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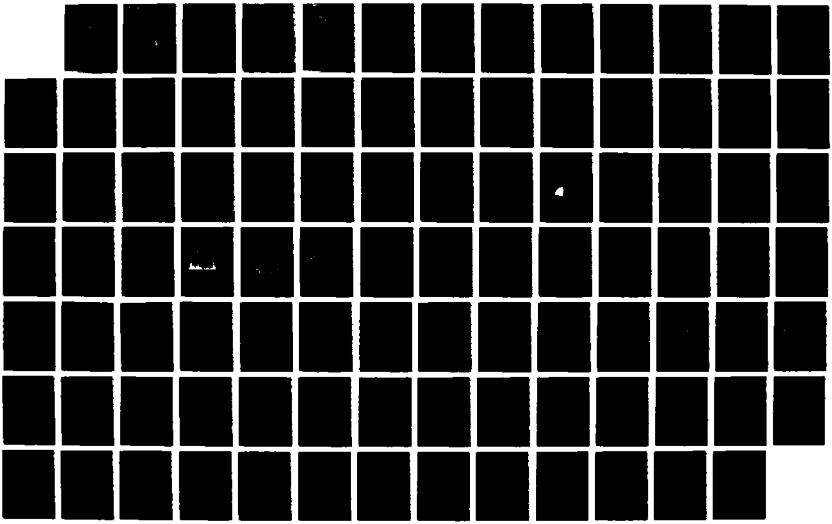

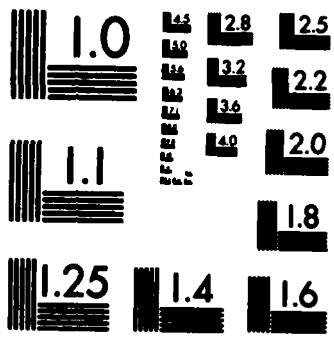

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A RAND NOTE

AD-A181 464

Using the Air Force Maintenance Data Collection System Data To Identify Candidates for Improvement in Reliability and Maintainability

R. L. Petruschell, G. K. Smith,
T. F. Kirkwood

March 1987

RAND

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This Note describes a preliminary and limited set of measures using data from the Air Force Maintenance Data Collection System (MDC) to identify likely candidates for reliability and maintainability (R&M) improvement. The method's usefulness depends on the user's having better than average knowledge of the MDC and of base-level maintenance. The MDC is a large, complex, and rich data system. Its magnitude alone is forbidding. The two-step method described shows how to distill these data, prepare useful metrics, and present these data in useful ways to R&M decisionmakers. Site investigations and interviews should be conducted to check the reasons for any high maintenance activity and to understand variability among bases before any R&M improvement program is instituted on a particular system or component.

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Prepared for
The United States Air Force

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PREFACE

The objective of the work reported in this Note is to develop a family of analysis methods for using the Air Force Maintenance Data Collection (MDC) system data to identify aircraft systems, subsystems, and components that are likely candidates for improvements in reliability and maintainability (R&M). The authors describe an illustrative method and demonstrate its use by applying it to the 1984/1985 worldwide F-16 A/B fleet. They also present the results of some preliminary research done to validate the MDC data for R&M decisionmaking.

This research is one part of a broader study of alternative policies and strategies to enhance the combat effectiveness of Air Force aircraft weapon systems through R&M improvements. Other parts of the study address the use of MDC data in the analysis of possible benefits from postulated R&M improvements and will develop ways to improve utilization of MDC data at base level. The work reported here is limited in scope and is intended only to illustrate the MDC analysis methods that the authors believe could and should be developed and implemented to support R&M resource allocation decisions.

This work is being conducted in RAND's Resource Management Program under the Project AIR FORCE study effort "Methods and Strategies for Improving Weapon System Reliability and Maintainability." It is directed primarily to the analytical staff that will develop and monitor Air Force aircraft R&M improvement programs. It should also be of interest to senior Air Force officials concerned with acquisition and logistics management.

SUMMARY

The research reported in this Note was done in support of the Air Force Reliability and Maintainability office, AF/LE-RD. That office is a focal point for activities aimed at improving the Air Force's ability to identify reliability and maintainability (R&M) problems with current and future weapon systems, to select systems, subsystems or components where improvement is both desirable and feasible, and to institute programs to improve R&M. It also sets R&M improvement goals and monitors progress. A system for reporting the R&M status of the operating forces is fundamental to the activity of that office.

This Note describes a preliminary and limited set of measures using data from the Air Force Maintenance Data Collection System (MDC) to identify likely candidates for R&M improvement. The MDC data is first used to prepare analysis data files. Then we use these files to screen or identify particular aircraft systems, subsystems, or components that are likely candidates for R&M improvement. A fundamental assumption is that a lot of maintenance activity on a particular system suggests that the system has either a reliability or a maintainability problem or both. The method is clearly the end product, but its usefulness depends almost completely on the user's having better than average knowledge of the MDC and of base-level maintenance. For that reason, the exposition includes considerable discussion of problems with the database and how it was substantially reconfigured for R&M analysis. Then a screening exercise illustrates with a rather complete example how the method would be used. The exposition concludes with a discussion of the sources of variability in the data and how that might influence R&M decisions.

The method was developed using the MDC data for the 1984/1985 worldwide F-16 A/B fleet. The example showing how to use the data to select candidate systems concludes that the Fire Control Radar Set, the Fire Control Radar Low Power RF Unit, the Fire Control Inertial Navigation Set, the Weapons Rack system, and the Stores Management system are the primary F-16 A/B candidates for R&M improvement. Current conventional wisdom would probably agree, so in and of itself this is

not new information. However, the method provides a quantitative statement of how serious the problem is and indicates that more than half of the maintenance jobs on these systems are unsuccessful attempts to duplicate pilot observed malfunctions. In other words, in more than half of the instances of unscheduled maintenance, nothing is fixed.

Some users of MDC output believe that the data quality is so poor as to be nearly worthless. Lack of quality control, differences in understanding of how and why to report maintenance information, data processing problems, and just plain errors are among the many reasons cited. To understand the extent of this problem we compared 1984 MDC data from the 388th Tactical Fighter Wing at Hill AFB with that from the 58th Tactical Training Wing at Luke AFB. Specifically, we identified approximately a dozen work unit codes for which the differences between the two bases were the largest and visited the bases to determine the reasons for the differences. We found that most of the variability for those items resulted from differences in maintenance policy, aircraft age, climate, and operational mission. Although MDC data do suffer from some quality problems, we found them adequate for many analysis purposes.

MDC is a large, complex, and very rich data system; it is a valuable source of data for getting a first order fix on Air Force aircraft R&M problems. However, there are no built-in metrics to use as simple indexes of R&M performance. The magnitude of the MDC database alone is forbidding. The two-step method described here shows how to distill these data, prepare useful metrics, and present these data in ways that are useful to R&M decisionmakers. We suggest that, after files identifying R&M improvement candidates are created, site investigations and interviews should be conducted to check the reasons for any high maintenance activity (and to understand variability among bases) before an R&M improvement program is instituted on a particular system or component. The MDC data alone do not explain why there are R&M problems, and they are not sufficient for making final decisions; yet they are very useful for raising questions and for examining candidates for R&M improvement programs.

ACKNOWLEDGMENTS

The work reported here would not have been completed without the help of several Air Force people who provided us with invaluable knowledge and insights regarding base level maintenance and the Air Force Maintenance Data Collection (MDC) system. We are particularly indebted to Chief Master Sergeant Donnie Hallam and Sergeant George Buchanan of the 388th Tactical Fighter Wing at Hill AFB, and to Sergeant Steve Yarosch of the 58th Tactical Training Wing at Luke AFB, for informing us about the technical side of MDC and about base level maintenance.

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I. INTRODUCTION

The Air Force is making a concerted effort to improve the reliability and maintainability (R&M) performance of its weapon systems, both those now in the force and those proposed for future development and procurement. The effective management of such an effort depends critically on our ability to measure and to record the R&M performance of our current systems. We then need to be able to draw from such a database a wide variety of information on the kinds of R&M problems being experienced and their relative importance to system availability and mission performance. Such information could support resource allocation decisions for modifying current equipment to improve its R&M performance and sharpen our understanding of how to write R&M requirements for future systems.

The Air Force does not have a data collection and recording program specifically designed to accommodate R&M management information needs. It does have an extensive and longstanding program to collect and record *maintenance* data on all of its systems and equipment items. The Maintenance Data Collection system (MDC) and its associated historical database (D056) can satisfy many of the needs for R&M data. However, because of the way MDC data are collected and organized, extracting R&M information is surprisingly complex. This Note describes the preliminary results of research designed to improve the Air Force's current methods for extracting R&M data from the D056 database.

STUDY OBJECTIVES

There have been many past efforts, by RAND and others, to utilize MDC data for analysis and management information purposes. Currently, the Air Force publishes several D056 analysis products that deal with R&M in one way or another. Those routine products do not fully exploit the available information in terms useful to R&M managers.

Given limited resources for making R&M improvements, Air Force managers will ultimately need to make R&M resource allocation decisions at several levels--which weapon system? which subsystem? which components? Specifically, we need methods for highlighting systems, subsystems, or components that are candidates (not necessarily final selections) for R&M improvement programs. We call this first order selection process "initial screening." Final choices will generally be made from among the candidates selected during initial screening.

We emphasize the word "candidates" because, even though we can identify a system, subsystem, or component that is receiving more than the usual amount of maintenance attention--hence is a likely candidate for R&M improvement--from these data, we cannot say anything directly about whether improving the R&M of that system is cost effective, or even feasible. We hope to provide an effective method for performing an initial screening to limit the targets to a manageable number.

APPROACH

The MDC Database

We used the MDC database because it is available. Much of what the MDC contains is clearly relevant to R&M. It covers most, if not all, of the important weapon systems. It has been around long enough to contain important information on historical trends. It promises to be around for some time in the future. It is more or less understood by a wide range of Air Force people. And it is the only game in town.

Data from MDC are widely published and supposedly used for many different purposes, not the least of which is for R&M decisionmaking. AFALD Phamphlet 800-4, "Acquisition Management Aircraft Historical Reliability and Maintainability Data," published by the Deputy for Engineering and Evaluation, Air Force Acquisition Logistics Division,[1] Wright-Patterson AFB is a prime example. That document contains voluminous information about maintenance manhours, mean times between failures, aircraft inventory, flying hours, sorties, landings, etc. by MDS, Work Unit Code, etc. Those data summarize the MDC data prepared through the Air Force Logistics Command D056 system. Unfortunately, they are not in a form particularly useful to the R&M community.

[1] Now called Air Force Acquisition Logistics *Center*.

Scope of Research

Many R&M issues can be addressed through use of the MDC database. The R&M characteristics of subsystems and components could be measured in terms of their effects on aircraft operational availability, on the requirements for maintenance resources, on the probability of mission success, etc. Each such analysis objective would require that appropriate (and in many cases different) metrics be derived from the MDC data. For example, analysis of resource consumption would require examination of maintenance manhours (by skill), utilization of support equipment, spares consumed, etc.

The analysis could also be directed toward different kinds of base-level maintenance--flightline maintenance, intermediate-shop maintenance, scheduled maintenance, support general, etc. Different and perhaps equally important insights might be obtained by examining each of these areas.

Because our objective was to illustrate a general process, and because time was limited, we directed our initial investigations toward only a small subset of the possible R&M issues. Specifically, we tried to identify the relative importance of R&M problems in different systems and components by looking at the malfunction occurrence rate, manhour consumption, and the time required to perform unscheduled on-aircraft maintenance. Further analysis, especially of repair shop actions, would be necessary to understand the full extent of resource consumption caused by each malfunction and to identify the appropriate corrective action.

Methodological Difficulties

The key difficulty involved in using the D056 database for examining R&M problems in terms of frequency of occurrence, manhours consumed, and elapsed times is that the basic item of information is a record describing a *maintenance action*. There is no direct way to determine the number or kind of *equipment problems* that led to those maintenance actions. The R&M manager, of course, is interested in determining what went wrong with the equipment. Therefore, a necessary first step is to translate the MDC data into a "problem-oriented" file rather than an "action-oriented" file.

Our research has consisted of efforts to solve four related methodological difficulties:

- How to define a set of maintenance activities that were related to resolving one maintenance problem. We call that basic unit of activity a "maintenance job."
- How to distinguish between reliability problems and maintainability problems.
- How to display the data in ways that are useful for R&M decisionmaking.
- How to deal with problems of variability in the data.

The Maintenance Job. We needed to be able to count maintenance "problems" (each occurrence of something wrong with the weapon system that required a corrective action) rather than the actions that went into solving (or trying to solve) the probems. MDC has provided the Job Control Number (JCN) to aggregate maintenance actions into something like a job, but unfortunately the rules for assigning JCNs are not followed rigorously enough to make them truly useful. One of our first research problems was therefore to summarize the MDC data to indicate jobs (all activities in response to a single problem) rather than maintenance actions--troubleshooting, removing a part, testing a subsystem, etc. Fixing a particular failed component may require one or many different maintenance actions. For example, when a component failure is reported, the following sequence of maintenance actions is common:

1. Troubleshooting on the system or subsystem of which the component is a part.
2. Identifying and removing the faulty component.
3. Drawing a serviceable component from supply and installing it on the aircraft.
4. Running an operations check on the system or subsystem.

For this job, the MDC would report four separate maintenance actions. Another time, given exactly the same circumstances with respect to the failure, the problem would be solved with a single remove-and-replace maintenance action. If one were to count maintenance actions as R&M problem indicators, one would count four in the first instance and only one in the second, obviously the wrong way to do it. Each of these cases should be considered a single maintenance job.

Distinguishing Between Reliability and Maintainability Jobs. The words reliability and maintainability are usually used in a single phrase such as "we are looking for R&M problems." The inference is that there is a single sort of composite problem. In fact, there may be one or the other or both of two different kinds of problems, and we believe that distinguishing between them will be an important aid to R&M decisionmakers.

Suppose that the goal of an R&M improvement program is simply to increase aircraft availability and that the main reason for the aircraft's being unavailable is the apparent failure of a particular component. Suppose the problem was simply that the component failed (broke) frequently and had to be replaced. Identifying the part was easy, the component was quickly replaced, but the aircraft was in maintenance a large fraction of its time simply because the component failed frequently. The problem is clearly a component reliability problem. The fix is straightforward. Make the component more reliable.

Suppose, however, that the problem was with a subsystem that the pilots continually reported to be malfunctioning. And furthermore suppose that typically the maintenance people were unable to duplicate the problem and hence were unable to fix it. The apparent failure may be real but intermittent. It may have been a manifestation or reflection of a problem with a completely different subsystem. Or it may have been the result of a failed component but one that is next to impossible to isolate. This problem is quite different from the one described earlier. Here the solution is much more complex. Improved test equipment, more highly skilled maintenance technicians, redesign of the entire subsystem, or any combination of these may be required. This is primarily a maintainability problem, and it is important to be able to distinguish between that kind of problem and a reliability problem. The research question is how to use the MDC data to make this distinction.

Display Data for R&M Decisionmaking. Still another problem results from the fact that the data are presented in the form of a raw database, not in a form that is useful for decisionmaking. This entire research effort has been involved with how to distill, digest, and display these data in ways that are useful to R&M decisionmakers. It is not an easy problem to solve even with the data in machine readable form and with access to large amounts of computing capacity. It is probably impossible without this capacity.

Variability in the MDC Data. The MDC is a large and rich database. It reports very detailed information about an even larger and more complex maintenance activity. Obtaining a sufficient understanding of these data is not a simple problem. Individual data elements may vary inconsistently over time and be out of line with the same factors for other systems at the same time. A large part of the problem is that users just do not understand what the MDC data are. We have looked at these data at some length and are very aware that it is easy to find disturbing anomalies. Some of these anomalies do reflect real problems with the data--reporting errors etc. But the majority of them stem from important real differences that the R&M decisionmaker should be aware of. The D056/MDC data are just not sufficiently rich to distinguish between the two. We have therefore tried to provide some insights about why these differences occur and to illustrate a method for both identifying and explaining them.

A Case Study

We used the MDC data for the 1984/1985 F-16 A/B fleet as a sample database to develop a method for selecting candidates for R&M improvement. The F-16 A/B fleet is an important part of the present Air Force and will continue to be so for some time in the future. And it is large enough and varied enough to provide most, if not all, of the research problems that will need to be solved.

In 1984 there were eight F-16 A/B operating wings located at eight bases. Three of these were Tactical Fighter Wings based in the continental United States (CONUS), three more were overseas based Tactical Fighter Wings, and the remaining two were CONUS based Tactical Training Wings. Together, these F-16 A/Bs flew 126,700 sorties in 1984 and 134,503 in 1985. Table 1 provides a breakdown of these data by base and operating unit.

Table 1

NUMBER OF SORTIES BY OPERATING UNIT

Base	Operating Unit	Number of Sorties 1984	Number of Sorties 1985
Hill	388th TFW	25500	24997
Nellis	474th TFW	17600	25591
Shaw	363rd TFW	12900	7892
Hahn	50th TFW	15600	15628
Kunsan	8th TFW	12200	13024
Torrejon	401st TFW	14100	15859
Luke	58th TTW	11200	10960
MacDill	56th TTW	17500	20552
Total		126700	134503

In subsequent discussions, we refer to the individual operating units using the name of the base alone. In most cases, there are other operating units on these bases. But for convenience, when we refer to Hill we are referring only to the 388th Tactical Fighter Wing; when we refer to Luke, we are identifying the 58th Tactical Training Wing, etc.

BASIC CONCLUSIONS

Our research and analysis of the MDC database and the D056 system in general and on the 1984/1985 F-16 A/B fleet database in particular have led us to the following conclusions:

- Contrary to widespread opinion, the MDC database is a valuable source for getting a first order fix on aircraft reliability and maintainability problems.
- Our two-step method of (1) distilling and reconfiguring the MDC database and (2) screening aircraft systems, subsystems, and components is a considerable help in identifying R&M improvement candidates.
- The MDC data do not explain why there are R&M problems, and they are not adequate for making final decisions on improvement programs; yet they are quite useful for raising questions and for focusing more indepth queries.
- The initial screening should typically be followed by site interviews and investigations to check the reasons for any high maintenance activity and to better understand the variability in the data at different bases, before R&M improvement program is instituted on a particular system or component.
- Variability in the data is important and should not be dismissed or overlooked.

OUTLINE

The remainder of this Note describes the two-step method we have developed. To emphasize the need to thoroughly understand the data and the maintenance activity in general, we have included more supporting material and discussion than we might otherwise have done. Although we may not have presented enough for everybody, we do hope that our illustrations and examples will motivate potential serious users of these data to carry on from here.

Section II identifies the part of the MDC database that we have used and describes how we prepared the analysis databases by reconfiguring data to create three successively smaller, more specific files. We also discuss why and how we have defined "Jobs" and assigned "Jobs" to categories primarily to distinguish between reliability jobs and maintainability jobs. In Sec. III, we illustrate the second step of the method--the process of screening the data--actually using the analysis databases to identify F-16 A/B candidates for R&M improvement.

In the screening process, we present the data in various ways to highlight potential problems and to identify potential candidates for R&M improvement. We comment extensively as we go so that interesting problems and possible solutions can be presented in context. In Sec. IV, we present the results of some preliminary work that we have done to discover why there is so much variability in the MDC data. Most important, we discuss the influence of this variability on the usefulness of the MDC database for R&M decisionmaking.

II. PREPARING THE ANALYSIS DATA FILES

In this section we prepare and explain how to create an analysis database for screening candidates for R&M improvement programs--the first of two steps in the method we developed for identifying such candidates. We indicate exactly where we obtained the data for our analysis, why and how we prepared our smaller analysis data files, how we defined a maintenance job, and how we assigned maintenance jobs to one of four different job categories--"remove and replace," "minor repair," "no defect found," and "other." We conclude with a statistical description of the 1985 F-16 A/B jobs at Hill AFB in each of these four job categories.

D056 DATABASE

The only single source for worldwide MDC data that we know of is in the D056 system maintained at Headquarters Air Force Logistics Command (AFLC) at Wright Patterson Air Force Base. Each operating base transmits copies of its MDC files to AFLC once every month. AFLC edits certain records; eliminates duplicate records; drops certain of the variables and adds a few variables for its own use; adds activity data such as sorties; combines the files from each base into fewer, larger files; and uses these data to prepare various reports. None of the original MDC data that we have found useful is lost in this process. So we have used the AFLC D056 data files rather than attempt to collect original MDC data from each pertinent Air Force base.

Much of the information contained in the D056 files was not relevant to the task of looking at on-aircraft unscheduled maintenance, so we discarded it. Furthermore, the files were not structured appropriately for our purposes, so we substantially reconfigured them.

THREE ANALYSIS FILES

We prepared three analysis files from the D056 data. In the order in which they were prepared, they are the Bases File, the Jobs File, and the Counts File. The order in which they were created reflects the course of our research to extract the data from D056 that we believed useful for R&M decisionmaking.

The Bases File

The D056 database is very large. For one year alone, the F-16 A/B file consists of almost one million records. We needed to create a more manageable file. Our first step was to eliminate all of the records that would be of little use for deciding how to improve the R&M of the F-16 A/B aircraft. For example, we discarded all records regarding scheduled maintenance, maintenance of equipment other than aircraft, and maintenance charged to Support General. We then sorted the results into individual files for each air base. The reasons for doing this will become clear later. The result was the still large but much smaller Bases File (about one-quarter of a million records).

The Jobs File

At that point, we confronted the question of how to define a maintenance job. We sorted the Bases File and managed to put the individual records in groups, each of which was believed to be a single maintenance job. We assigned a unique job number[1] to all records in each of these groups, selected a single record from each group (according to a procedure described below), and came up with the Jobs File (roughly half the size of the Bases File).

The Counts File

Next we developed a scheme for distinguishing among four different kinds of jobs: "Remove and Replace," "Minor Repair," "No Defect Found," and "Other." We assigned another code reflecting this distinction to

[1]The Job Control Number (JCN) provided by MDC was not adequate for our purposes. Why will be explained later.

each job in the Jobs File. Finally, we summarized all of the data in the Jobs File by a 4-digit work unit code (WUC). We added WUC titles from the Work Unit Code Dictionary[2] to this file and had the much smaller and more manageable Counts File, the file that we generally used for counting the frequency of different kinds of jobs. Each of the three analysis files may be thought of as a single file or as a group of subfiles--one subfile for each base. We actually did most of the data processing one base at a time.

Our original intent was to use the Counts File for all subsequent analyses. And for the most part we did. However, as the analysis progressed, we frequently raised questions about the data in the Counts File that we were able to resolve by looking back at either the Jobs File or the Bases File. We seldom had to refer back to the complete D056 database. In fact, the ability to refer back to successively lower levels of detail as the need arose was so useful that we now regard all three of these files as equally important parts of the R&M analysis database.

We also constructed a fourth file--the Sortie File. It contains monthly sorties by MDS and was obtained directly from the D056 "L" records. We needed these data to calculate malfunctions per sortie. The process of creating this was a straightfoward extraction of records from D056 and will not be described further here.

PREPARING THE FILES

Preparing the Bases File

We used the D056 files (MDC data) for calendar years 1984 and 1985 for each of the eight bases that operated F-16 A or B aircraft. All base-level maintenance actions reported in MDC are included in D056. Each record (maintenance action) carries a record type code, and the list of different record types (see Table 2) suggests the kinds of maintenance activities that are recorded in D056.

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[2]We obtained a machine readable copy of the Work Unit Code Dictionary (B-4 master tape) from Headquarters Air Force Logistics Command.

Table 2

D056 RECORD TYPES

Record Type Code	Record Description
A	On equipment aircraft, missile, JETD, C-E, also TCTO data
E	On equipment engine, also TCTO data
G	On equipment nonairborne, also TCTO data
H	Off equipment, also TCTO data
P	Parts replaced during repair
R	Removal and installation of serialized components
S	Summarized aircraft support general
T	Removal and installation of aircraft engines

More aircraft availability and more sortie generation potential are among the major reasons for improving reliability and maintainability. We reasoned that the amount of unscheduled maintenance performed directly on the primary mission aircraft would be the best indicator (from MDC/D056) of those reliability or maintainability problems that directly affect aircraft availability, hence sortie generation potential.

We kept only type "A" (on equipment) records with Type Maintenance codes "B" (unscheduled maintenance) or "P" (periodic, phased, or major inspection).[3] Type maintenance codes are shown in Table 3. We also kept only those records that reported work done directly on F-16 A or B aircraft belonging to the Tactical Air Command (TAC), the Air Forces in Europe (USAFE), and the Pacific Air Forces (PACAF). We eliminated all records reporting work on F-16 A/Bs belonging to the Air Force Reserve and the Air National Guard units. The remaining records constitute the Bases File, our primary analysis database.

[3]On aircraft maintenance includes maintenance performed on the engine while it is "installed" in the aircraft. Record type "E" (On equipment engine) covers work performed while the engine is removed from the aircraft. It was therefore omitted from this analysis. We considered the removal of serialized components as scheduled maintenance, hence omitted the "R" records.

Table 3

AIRCRAFT RELATED MAINTENANCE TYPE CODES

Record Type Code	Maintenance Description
A	Service
B	Unscheduled maintenance
C	Basic postflight and through-flight inspection
D	Preflight inspection
E	Hourly postflight or minor inspection
H	Home station check
J	Calibration of operational equipment (non-PME)
P	Periodic, phased, or major inspection
Q	Forward support spares
R	Depot maintenance
S	Special inspection
T	Time Compliance Technical Order (TCTO)
Y	Aircraft transient maintenance

SOURCE: Aircraft Maintenance Work Unit Code Manual, USAF/EPAF Series F-16 A/B Aircraft, T.O. 1F-16A-06, 25 February 1985.

The original D056 files contained roughly one million records of about 100 characters each--100 megabytes of data. The Bases File, including all eight bases, contains about 250,000 records of the same length or 25 megabytes. The Bases File is still very large, but it is considerably smaller and more tractable than the original D056 file. In 1985, the individual base subfiles ranged in size from about 65,000 records for MacDill down to about 8,000 each for both Kunsan and Shaw.

Preparing the Jobs File

More About the MDC/D056. To better understand both how and why we constructed the Jobs File, we digress to provide a few more insights into the MDC/D056 and base-level maintenance. We trust that those who are already familiar with these systems will bear with us.

The source document for information input to the MDC and hence to D056 is the Form DD349, which contains all of the maintenance information reported regarding a maintenance task. Each line is a single maintenance action. The DD349 also shows the tail number of the aircraft worked on; the WUC of the system or component; the work center of the maintenance people who did the work; how many maintenance people were involved; when they started and when they finished; the circumstances under which the problem was discovered; the basic fault, if one could be identified; the kinds of maintenance actions that were taken to cure the fault; and considerable additional information that is not of particular interest here.

In principle, all maintenance actions undertaken to cure a particular fault should be recorded on a single DD349. Furthermore, each DD349 should be identified with a single seven-digit Job Control Number (JCN). The first three digits of the JCN are the julian day on which the JCN is issued, and the last four digits are numbers issued, in sequence, by the Performing Work Center (PWC). Each PWC typically has its own set of 4-digit numbers that it recycles each day starting in the morning and continuing through the day as maintenance tasks arise.

Table 4 contains a sample of the the DD349 data in the Bases File. Essential data from four JCNs and hence four DD349s are presented.

JCN 1789619 reflects work performed on aircraft tail number "A".[4] Each line recorded for that JCN reports on a single maintenance action. The entire task consisted of four maintenance actions. All of the maintenance actions were accomplished by Aircraft Systems Specialists. WUC = 41A00 (App. A) indicates that the trouble was with the Air Conditioning Subsystem, and WD = D (App. B) indicates that the pilot discovered the problem during a flight; furthermore, the problem was not sufficiently bad to cause him to abort the mission. HMAL = 242 (App. C) says that for unknown reasons the environmental control system failed to

[4]The data shown in Table 4 and again in Table 5 are provided to indicate why we found it necessary to assign job numbers and to illustrate the kind of information that can be obtained from the DD349 forms. We have used an arbitrary indicator of aircraft tail numbers and omitted certain other information from the tables to avoid identifying the reporting organizations.

Table 4

TYPICAL JOB CONTROL NUMBERS
(Form DD349 data)

Specialist	Tail	WUC	ATC	WD	HMAL	Units	Start	Stop	Crew	Job
JCN 1789619										
Aircraft	A	41A00	Y	D	242	1	1400	1500	2	1
Systems	A	41ACA	P	D	242	1	1500	1800	2	1
Specialists	A	41ACA	Q	D	242	1	1900	2130	2	1
	A	41A00	X	D	799	1	2130	2200	2	1
JCN 1786140										
Crew Chiefs	B	13DBB	R	F	20	1	1900	1930	1	2
JCN 1786201										
Egress Systems										
Specialists	C	12CA0	L	F	730	1	1600	1700	2	3
JCN 1789776										
Attack/Flight	D	74A00	Y	D	290	1	1530	1700	2	4
Control & Navig.	D	74AB0	R	D	290	1	1730	2000	2	4
Systems Specs.	D	74A00	X	D	799	1	2000	2045	2	4

WUC = Work Unit Code. WD = When Discovered Code
ATC = Action Taken Code. HMAL = How Manfunctioned Code

operate. The start and stop times show when each maintenance action started and ended.

Collectively, the individual maintenance actions tell the following story about what was done to deal with the problem. At 1400 two aircraft systems specialists started troubleshooting (ATC = Y, see App. D) the environmental control system. They worked for one hour and apparently localized the problem to the Cabin Air Temperature Control (WUC = 41ACA). Immediately after that, they spent three hours removing the control (ATC = P) and another two and one-half hours installing a new control (ATC = Q). They had the new control installed by 2130 and then spent 30 minutes checking out the whole environmental control system (ATC = X and WUC = 41A00). The HMAL of 799 indicates that they found no defect, so all was well. The job took seven clock hours and 14 manhours to complete.

This exercise provides the reader with a little insight into MDC; furthermore, we need this example to set the stage for what comes next. Going through the other three JCNs is left to the reader. All necessary information is contained in the various tables and appendixes.

The Problem with JCNs as Indicators. All of the lines and maintenance actions recorded against a single JCN (on a single form DD349) should relate to fixing or solving a single maintenance problem--a fault in a single subsystem or component. If JCNs were used in that way, then the number of JCNs reported against a subsystem or component per unit time would be a useful indicator of the reliability, the maintainability, or both of that particular subsystem or component. That kind of an indicator is exactly what we were looking for.

Unfortunately, life is never simple. In some cases, several different maintenance tasks (Jobs) are reported under the same JCN. One of these cases is illustrated in Table 5, in which a single JCN reflects work done at one particular base in October 1984. Work under that JCN was performed, over the course of a day, on five different aircraft and four different subsystems: on the flight control system on aircraft "E", on the exterior lighting system and on the landing gear of aircraft "F", on the landing gear of aircraft "G", on the landing gear of aircraft "H", and on both the exterior lighting system and the landing gear of aircraft "J". As shown in the right hand column of Table 5, this collection of work could reasonably be broken down into seven separate jobs. In the Jobs File, it will be.

The Need to Define Jobs. We needed to define something that we could count, and we needed to recast the database so that we could in fact make these counts. We defined the "Job" as our counting unit. If all of the JCNs were like the ones illustrated in Table 4, we would have said that a Job is a JCN and been done with it. However, because of JCNs like the one described in Table 5, we could not do that. *We defined a Job as that work done on a single aircraft, on a single two-digit work unit code, and under a single JCN.*

We also wanted to choose the single record or maintenance action from each Job that best characterized that Job for R&M analysis purposes--what kind of a job it was, what subsystem or component was

Table 5

EXAMPLE OF A TROUBLESOME JOB CONTROL NUMBER
(JCN #3216800, 16 October 1984)

Specialist	Tail	WUC	ATC	WD	HMAL	Units	Start	Stop	Crew	Job
Aircraft	E	14BB0	P	A	381	1	1000	1115	3	1
Systems	E	14BB0	Q	A	799	0	1600	1815	3	1
Specialists	E	14BB0	Q	A	799	1	1830	2000	3	1
	E	14B00	X	A	799	1	2000	2100	2	1
	E	14B00	X	A	799	1	2030	2130	3	1
	E	14000	X	A	799	1	1830	2130	2	1
Crew Chiefs	F	44AAB	R	F	80	2	100	200	1	2
	F	13DAB	R	F	20	2	2105	2200	2	3
Crew Chiefs	G	13DBA	R	E	20	1	1930	2030	2	4
	G	13DBB	R	E	20	1	2030	2130	2	4
Crew Chiefs	H	13DAA	R	B	20	2	800	900	1	5
Crew Chiefs	J	44AAB	R	H	80	1	1400	1430	1	6
	J	44AAE	R	H	80	1	1435	1500	1	6
	J	13DA0	R	H	20	1	1505	1600	1	7

worked on, what the problem was, when the problem was discovered, which aircraft the job was done on, etc.

Finally, we wanted the elapsed time and the manhours used to be included on that record. Time begins with the start time on the first maintenance action and ends with the stop time on the last maintenance action. Gaps are omitted in the calculation of manhours. For example, eight elapsed hours and 16 manhours were required for the job shown as JCN 1789619 (Table 4).

Creating the Jobs File. We started with the Bases File. All records with Action Taken Codes E, Q, or U were discarded. The E records indicate the initial installation of a component. That is irrelevant to R&M. The Q records indicate an installation and should always be accompanied by a P record, which indicates a removal. We dropped the Q records to prevent double counting. Similarly, U records indicate the replacement of a part after cannibalization, and they should always be accompanied by a T record, which indicates the removal of a part for cannibalization. We thus kept the T records and dropped the U records.[5]

We also dropped all records having the first two digits of the work unit code equal to 10 or less. These are records from the "look" phase of Phased Inspection and do not qualify as unscheduled maintenance. All of the "Fix" phase records are retained.

We assigned a different job number to each group of maintenance actions with a unique combination of aircraft tail number, JCN, and the first two digits of work unit code--the definition of a job. We then sorted the Bases File by job number to get ready to select the most representative maintenance action from each job.

Action Taken Codes seemed most relevant at this point. For example, because Q records have been eliminated, JCN 1789619 (see Table 4) now consists of three maintenance actions. All of the information about which subsystem or component failed or was otherwise at fault and what the fault was is contained in the P record. The P record tells us that the cabin air temperature control was the culprit and that, for reasons unknown, it failed to operate.

---

[5]P and Q records and T and U records should always exist in pairs. We know that this is not always the case. However, the number of times when only half of the pair is present is believed to be sufficiently small and the data processing task of checking sufficiently large that we could ignore this potential problem. This is an example of numerous decisions that have to be made in the process of "editing" MDC data. The "editing" problem has been recognized and dealt with by numerous MDC analysts in the past. The problem is not going to go away, and each future user must deal with it in a way that is suitable for his needs.

Similarly, in JCN 1789776 (also see Table 4), the most pertinent information is contained in the R record. We kept it and discarded the rest.

Suppose that in one job we had several R records, or several P records, or one of each. Suppose that there were no R and no P records, only X and Y records. Suppose that instead of R and P records we had a G record (replacement of minor parts) or an L record (adjust).

To deal with the question of which action taken code to select when there was more than one possibility, we established a preference list (see Table 6). Our first choice is an R, remove-and-replace record. Our second choice is a P record, and so on. Once a record is selected, we keep it and delete all of the other kinds of records for that job.

Table 6

PRIORITY FOR DEFINING JOBS BY ACTION-TAKEN CODES
(Only those codes relevant to on-aircraft
unscheduled maintenance)

Code	Action
R	Remove and replace
P	Removed
S	Remove and reinstall (to facilitate other maintenance)
L	Adjust
G	Repair and/or replacement of minor parts, hardware, etc.
V	Clean
F	Repair
K	Calibrated--adjustment required
Z	Corrosion repair
X	Test, inspect, service (Ops check)
Y	Trouble shoot
H	Equipment checked--no repair required
J	Calibrated--no adjustment required
T	Remove for cannibalization
Records with these codes deleted from the database	
E	Initial installation
Q	Installed
U	Replace after cannibalization

Now what if we have multiple records with the same action taken codes, and the action taken code is the one that we would normally select? Which one of the two or more records should we keep? This is important because one of our objectives was to be able to count these records, say by work unit code, as though they were jobs. Having some jobs with two or more records and some with only one makes doing such a thing difficult at best.

We simply sorted the file by job number and five digit work unit code and chose the first record from each job group. Because of the sort procedure, WUC = 41ACA would come before WUC = 41A00 and 41A00 before 41000. So by taking the first one, we got the more precise identification of the component at fault.

Finally, what if there are multiple R or P or some other type of record that we would normally select, and they are all defined to the full five digit work unit code level but each is for a different work unit code? Fortunately this does not occur often, but when it does, our method will pick only the one that occurs first.

Together all of the records selected (one per job) make up the Jobs File. Like the Bases File, the Jobs File contains separate subfiles for each of the eight bases. All of the information that was on records in the Bases File (for those records that we kept) is also on the records in the Jobs File. Furthermore, the records in the Jobs File contain additional information regarding the total elapsed time and the manhours used to accomplish the job. These data were calculated before the Bases File was split apart.

The Jobs File is roughly 65 percent of the size of the Bases File. The Bases File was roughly 25 megabytes and the Jobs File is about 15 megabytes.

Preparing the Counts File

The final step in reconfiguring the analysis database was to create the Counts File wherein we assigned jobs to categories to facilitate R&M analyses.

The Counts File is simply the Jobs File with each job assigned to one of four job categories--Remove & Replace, No Defect Found, Minor Repair, or Other. Which category a job is assigned to depends on both the How Malfunctioned Code and the Action Taken Code. We really didn't start out with these categories in mind. Rather they evolved as we looked at the jobs in the Jobs File and asked what each of them had to say about reliability and maintainability.

For example, an R or a P (action taken code) job with a How Malfunctioned Code of 70 (broken) clearly indicates a component that was broken and in that sense unreliable. A job with an Action Taken Code of Y (trouble shoot) and a How Malfunctioned Code of 799 (no defect) suggests that somebody thought that there was a problem with that component but, after trouble shooting, found none. Such a job might also indicate a reliability problem but, we believed, probably a maintainability problem.

Other combinations of Action Taken Codes and How Malfunction Codes suggested that the particular jobs had little or nothing to say about either reliability or maintainability--for example, the removal of a component (Action Taken Code R or P) because it was broken by improper handling (How Malfunctioned Code 86). Thus, we distinguished among removals due to a component failure of some kind, no-defect-found jobs, and not-relevant jobs. We noted still another class of jobs that we called minor repair. A job with an Action Taken Code of G (repair and replacement of minor parts) would fall into this category.

The actual assignments were made as follows. First, all jobs that we thought were irrelevant to R&M were identified and assigned to the "Other" category. The jobs that we assigned to "Other" have either one of the How Malfunctioned Codes shown in App. E or an Action Taken Code T, remove for cannibalization. When we made this selection, our emphasis was on identifying reliability problems. An analyst who was interested in maintainability might have made somewhat different choices.

Next, from the remainder, we selected all jobs with How Malfunctioned Codes of 672 or 799 or with Action Taken Codes of X or Y or H or J (see App. F) and assigned them to the "No Defect Found" category.

Of the jobs then remaining, those with Action Taken Codes of either P or R were assigned to the "Remove and Replace" jobs category, and all others were assigned to the "Minor Repair" job category. Finally, we added the Work Unit Code titles to all of the records in the Counts File.

JOB CHARACTERISTICS

Figure 1 shows that in 1985 roughly the same number of jobs were assigned to each of the four categories. Appendixes G, H, I, and J provide frequency distributions (counts) of the jobs assigned to each of the four job categories by When Discovered Code, How Malfunctioned Code, and Action Taken Code. Figures 2 and 3 are cumulative distributions of elapsed time to complete jobs and the manhours per job respectively.

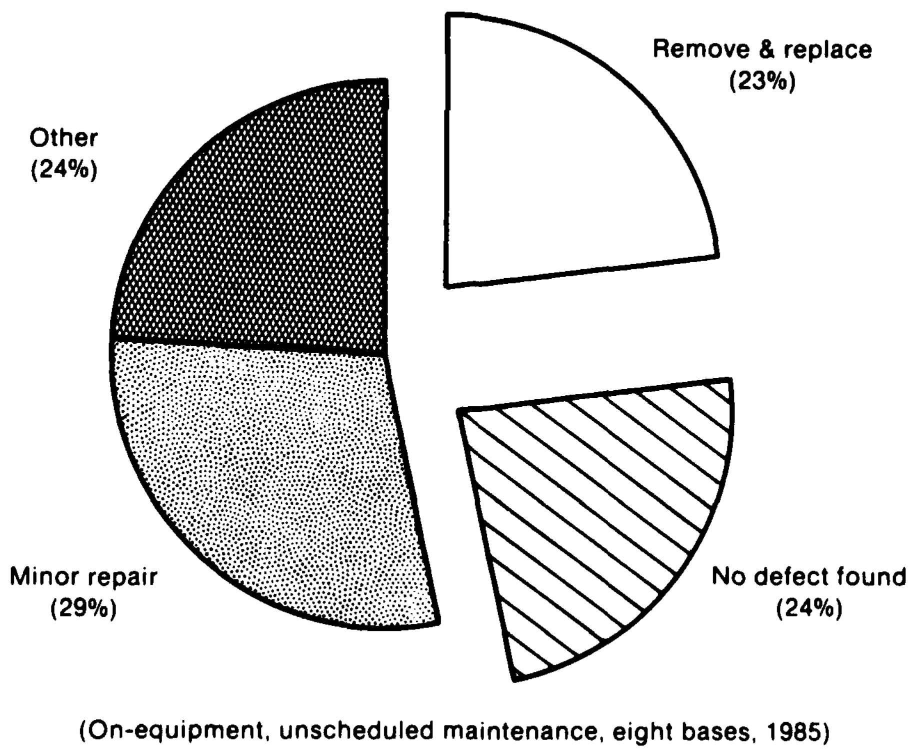

Fig. 1—Distribution of jobs by job type

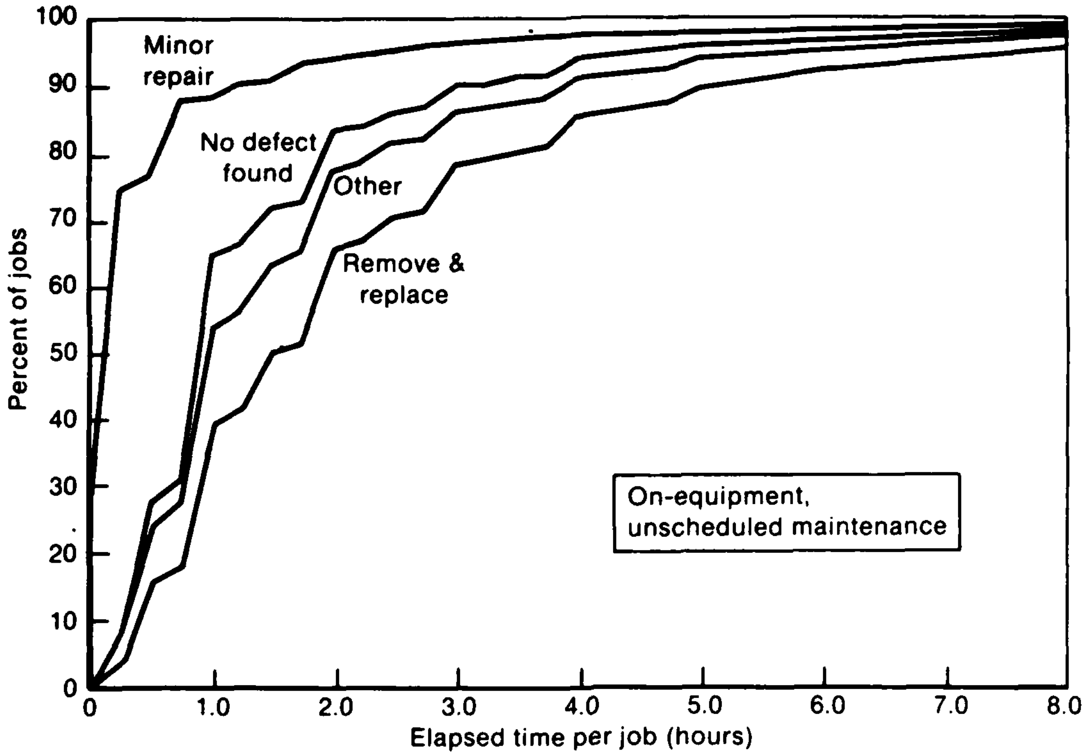

Fig. 2—Distribution of job duration, 388th TFW, 1985

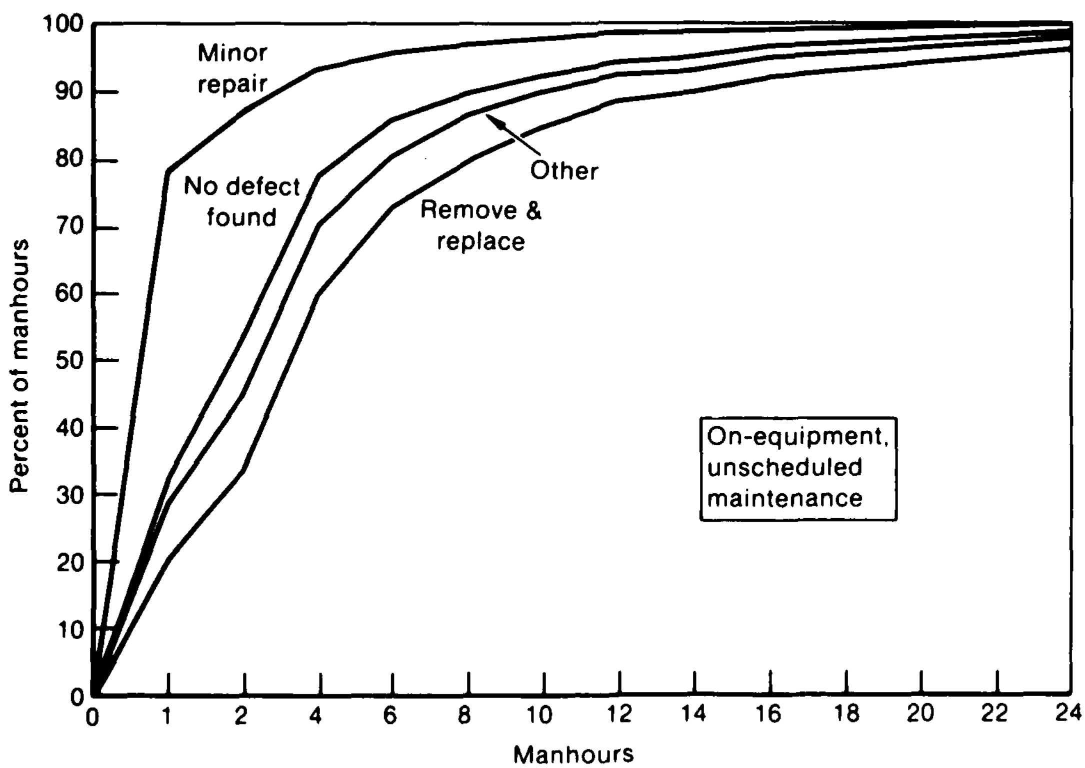

Fig. 3—Distribution of manhours per job, 388th TFW, 1985

These latter data are for 1985 and the 388th Tactical Fighter Wing at Hill AFB. Other bases and other years would probably yield slightly different results.

Remove and Replace Jobs

The first item of note (see App. G) is that over half of these jobs result from a pilot discovered problem. The When Discovered Code is D, meaning that the problem was discovered in flight but that it was not sufficiently bad to cause the peacetime mission to be aborted. This suggests that these jobs are reasonable indicators of reliability problems that could cause mission degradation if not fixed.

The frequency of occurrence by How Malfunctioned Code indicates that, in 20 percent of the cases, the reason for the failure was not known--How Malfunctioned Code is 242. More relevant, however, is the fact that some understanding of how the system or component failed was indicated for the other 80 percent of the jobs. This makes them even more interesting.

Furthermore, in 86 percent of the cases the component probably at fault was removed and replaced, as indicated by Action Taken Code R. And presumably the problem was fixed or thought to be fixed.

Figures 2 and 3 show that of the four categories of jobs, the Remove and Replace jobs required the longest time and the most manhours to accomplish: 50 percent of the Remove and Replace jobs were done in fewer than three plus manhours and one and one-half hours or less. At the extreme, roughly 10 percent of these jobs required more than 14 manhours and more than five elapsed hours to complete.

A job in this category suggests that there was a "reliability" problem--something broke. The problem was generally identified and fixed. Although these jobs are the longest and require the most manhours, for the most part they are not really long jobs. In subsequent discussions, we will use the number of Remove and Replace jobs occurring per unit time or per sortie as our primary index of "reliability" as opposed to "maintainability" problems.

No Defect Found Jobs

The No Defect Found Jobs (see App. H) are similar in some ways to the Remove and Replace Jobs. About half of them result from troubles discovered by the pilot in flight. Typically the fault was not serious enough to cause the peacetime mission to be aborted. Another 35 percent of the jobs resulted from problems discovered between flights by the ground crew.

More than 80 percent of the time no specific cause for the problem was identified--How Malfunctioned Code = 799 (no defect found) was assigned in 82.3 percent of the cases.

In 74 percent of the jobs the culprit subsystem or component was checked, tested, or serviced (Action Taken Code = X or H) and that was it. In another 14 percent of the cases some trouble shooting alone was indicated. Thus, in 88 percent of the cases no corrective action was taken.

One might conclude either that the pilots or the ground crews simply thought problems existed where they did not, or that there were really problems but the maintenance folks were unable to diagnose and fix them. Experience suggests that the latter is most often the case. Considerable fault isolation and diagnostic problems do exist, particularly when it comes to the avionics systems and subsystems. In many respects, this category of jobs is the most interesting from an R&M point of view--also the most difficult to deal with.

Figures 2 and 3 show that these jobs take less time and require fewer manhours to complete than do the Remove and Replace jobs: 50 percent of these jobs required less than one hour and less than two manhours. Apparently, not much time is spent looking for answers to tough questions. Exactly why is not clear, but the answer would be interesting.

The number of jobs appearing in this category appears to be, for the most part, an indicator of "maintainability" rather than "reliability" problems, and we use it as such. We use the word "maintainability" rather loosely here. The point is only to distinguish these jobs from the easier to understand and straightforward Remove and Replace jobs.

Minor Repair Jobs

The Minor Repair Jobs (see App. I) consist mostly of fixing or replacing minor items such as nuts, bolts, and fasteners, or making minor adjustments. As can be seen from the When Discovered Codes, almost 80 percent of these jobs are discovered and fixed during the fix phase of phased inspection.

Figures 2 and 3 show that these jobs are generally very short and require very few manhours to complete. Roughly 80 percent require less than one man for one hour.

We in no way mean to suggest that problems like these should be ignored. However, to limit the scope of this exploratory analysis, we will usually omit this category in our following discussions.

Other Jobs

This category (see App. J) contains those jobs we decided at the outset had little relevance to the problem of identifying candidates for R&M improvement. They are a mixed bag and include removals for cannibalization, removal of a functioning part to gain access to a broken part, etc.

The removal of the part that caused a hole to be filled with a cannibalized part is already counted in the Remove and Replace job category--usually a P Action Taken Code. The removals for access might, in fact, suggest a certain kind of maintainability problem and perhaps should be investigated in more depth.

III. A SCREENING EXERCISE

Once we have created the three analysis data files, our problem becomes that of how to use these data to obtain insights about the R&M status of the Air Force F-16 A/B fleet. The databases are rich, and there probably are an infinite number of ways to look at them--some better for some purposes than for others. We explore only a small fraction of the possibilities here and hope that they will be useful in their own right and also suggestive of other ways to use these same data. For example, even with our limited focus on on-aircraft unscheduled maintenance, our databases would permit us to use job counts, manhours, and/or elapsed times. Although the results would be somewhat different, the method would not be. *For illustrative purposes, therefore, we present a screening example using only job counts.*

THE GOAL OF INITIAL SCREENING

Remember that our goal is to identify aircraft systems, subsystems, or components that are potential candidates for R&M improvement. We emphasize "potential" for, with these data alone, we lack much that is essential to making the final selections.

We can observe that a particular subsystem or component is receiving a lot of maintenance attention, but we cannot really tell why. The data alone provide no real insights about whether the reliability or maintainability of a particular component could be improved. These data can even be misleading in some instances. Consider the case when several components are receiving a lot of maintenance attention, but the problem is caused by the failure of another component that may not be receiving much attention.

NEED FOR ADDITIONAL INFORMATION TO MAKE FINAL CHOICES

There is nothing fundamentally wrong with the MDC data. They just do not contain all of the information necessary to make the final R&M decisions. Furthermore, no new or improved data system will either. Information that will be critical in any given instance is just too varied and unpredictable to be recorded in any routine data collection effort. Each decision will probably need to be supported by special data collections and analyses, site visits, etc. MDC data can, however, be extremely useful to help focus these other activities and to raise questions. Attempting to answer these questions will produce a great deal of the knowledge and insights that are ultimately required.

A HIGH LEVEL VIEW

All Categories of Jobs

Table 7 provides a summary of the number of equipment unscheduled maintenance jobs per thousand sorties performed at all eight bases during calendar year 1985. The data are broken out by major aircraft system (2-digit Work Unit Code) and by type of job.

A glance at the totals in the right-hand column indicates that the single largest number of jobs was performed on the Airframe (WUC = 11). The Fire Control system (WUC = 74) is a close second, and Landing Gear (WUC = 13) is third. The Weapon Delivery system (WUC = 75) is next etc. Although numbers often provide some of us with a comfortable feeling, the graph in Fig. 4 does a much better job of showing the ranking.

One would like to believe that the system receiving the most maintenance attention is the best candidate for reliability or maintainability improvement. Unfortunately, it is difficult to put the airframe in the same category as the fire control system. Even the landing gear does not seem quite the same as the fire control system. Note that this ranking occurs when we consider all types of jobs together. Also the airframe jobs consist almost completely of "minor repair" and "other" jobs, and the fire control system jobs are predominantly remove-and-replace and no-defect-found jobs. Furthermore, for reasons discussed previously, we suggested that remove-and-replace was probably the best indicator of reliability and no-defect-found of maintainability problems.

Remove-and-Replace vs. No-Defect-Found Jobs

Figure 5 is similar to Fig. 4 except that the minor repair and the other jobs have been omitted. The same data are also plotted in Fig. 6.

Table 7

JOB COUNTS PER 1000 SORTIES, BY 2-DIGIT WORK UNIT CODE
(On-equipment, unscheduled maintenance eight bases, 1985)

WUC	Aircraft System	Remove and Replace	No Defect Found	Minor Repair	Other	Total
11	Airframe	4.25	7.57	97.05	63.27	172.14
12	Crew Station	5.91	7.06	11.49	20.00	44.46
13	Landing Gear	32.76	10.73	48.93	11.81	104.23
14	Flight Controls	18.79	17.75	23.15	16.19	75.89
23	Turbofan Power Plant	19.06	15.80	15.53	15.45	65.84
24	Auxiliary Power/JFS	9.65	12.59	14.92	27.17	64.33
41	Environmental Control	6.96	8.54	4.82	7.79	28.11
42	Elect. Power Supply	15.63	14.38	8.05	18.33	56.39
44	Lighting	22.49	4.50	12.79	2.19	41.96
45	Hydraulic & Pneumatic	3.86	3.20	8.23	3.25	18.54
46	Fuel System	15.58	23.80	19.59	15.11	74.08
47	Oxygen	3.64	4.07	2.61	3.56	13.88
49	Misc. Utilities	0.27	0.73	0.84	0.33	2.17
51	Flight Instruments	10.99	5.30	4.41	2.85	23.55
55	Malfunction Analysis & Recording	0.52	0.51	1.46	4.94	7.43
62	VHF Communications	3.77	3.76	10.67	0.66	18.86
63	UHF Communications	6.85	6.18	4.80	2.22	20.04
64	Interphone	1.64	1.64	1.55	0.34	5.17
65	IFF	3.51	4.04	11.70	1.55	20.81
71	Radio Navigation	2.57	3.21	1.37	0.95	8.10
74	Fire Control	41.55	49.21	13.67	22.67	127.10
75	Weapons Delivery	21.23	47.02	10.01	19.67	97.94
76	Penetration Aids & ECM	14.43	18.71	7.61	6.53	47.28
91	Emergency Equipment	0.03	0.23	0.13	0.02	0.41
93	Drag Chute Equipment	0.00	0.01	0.02	0.01	0.04
96	Personnel & Miscellaneous Equipment	0.09	0.17	0.24	0.07	0.57
97	Explosive Devices Etc.	0.25	0.28	0.16	6.30	6.99
	Total	266.28	271.00	335.79	273.25	1146.32
	Percent	23.8	23.6	29.3	23.8	100.0

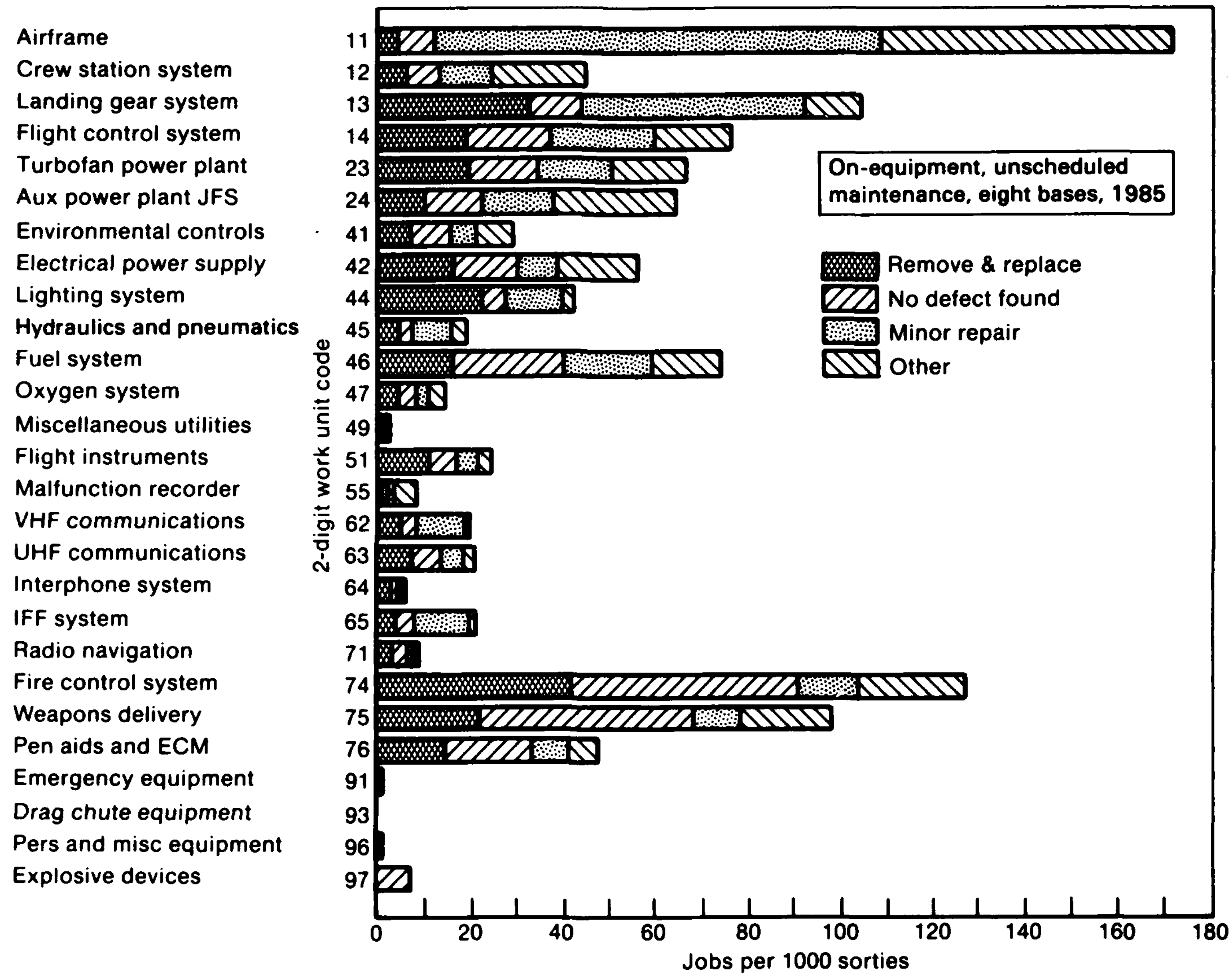

Fig. 4—Job counts per 1000 sorties, by 2-digit WUC

Here we highlight the relative contribution of the two different kinds of jobs.

If a system had only remove-and-replace jobs it would be plotted on the vertical axis. These jobs reflect cases where the maintenance personnel thought that they had both identified a specific problem and taken a specific corrective action. Conversely, a system with only no-defect-found jobs would be plotted on the horizontal axis. In these cases, although a problem was thought to exist, no specific fixable problem was identified and no specific corrective action was taken. Clearly these two situations suggest two substantially different kinds

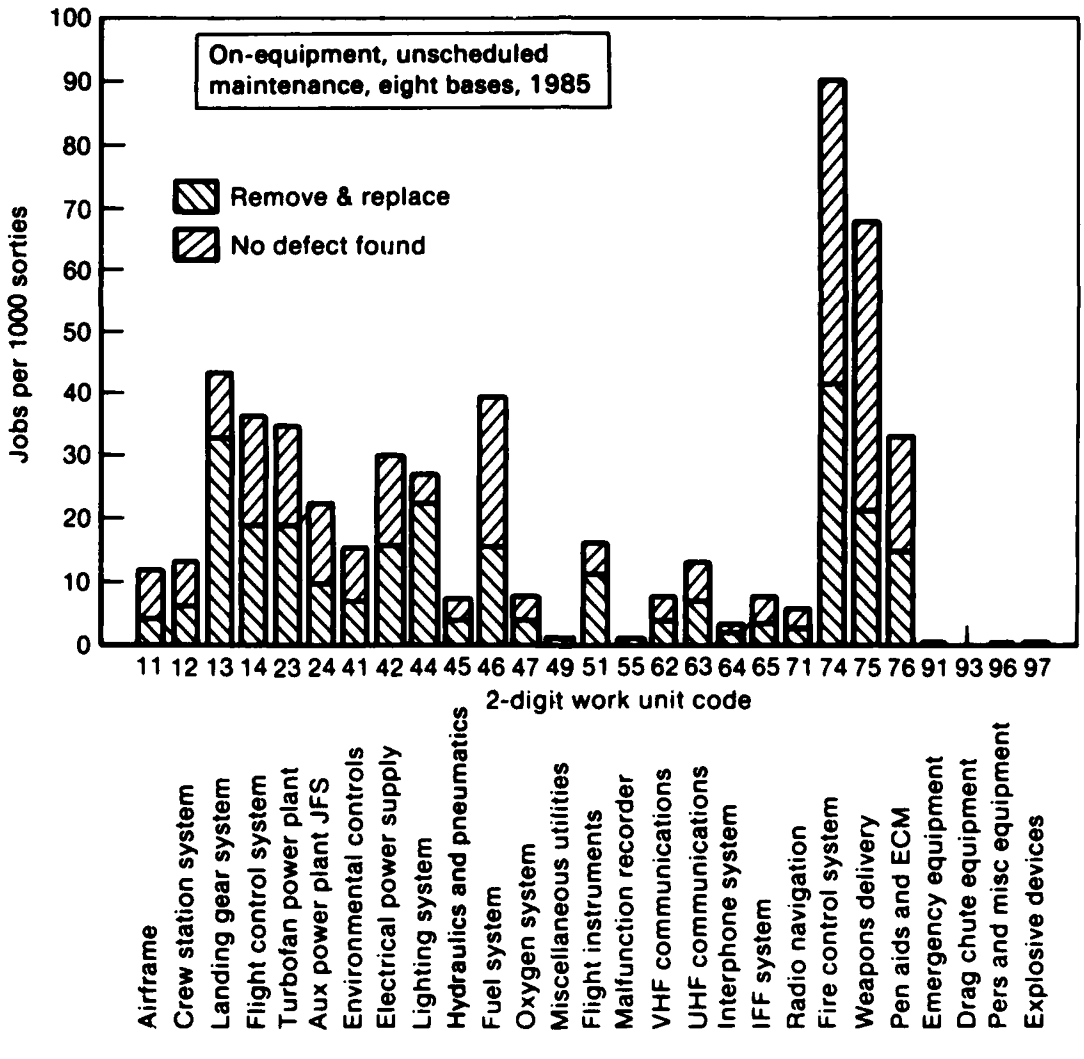

Fig. 5—Remove/replace and no-defect-found job counts by 2-digit WUC

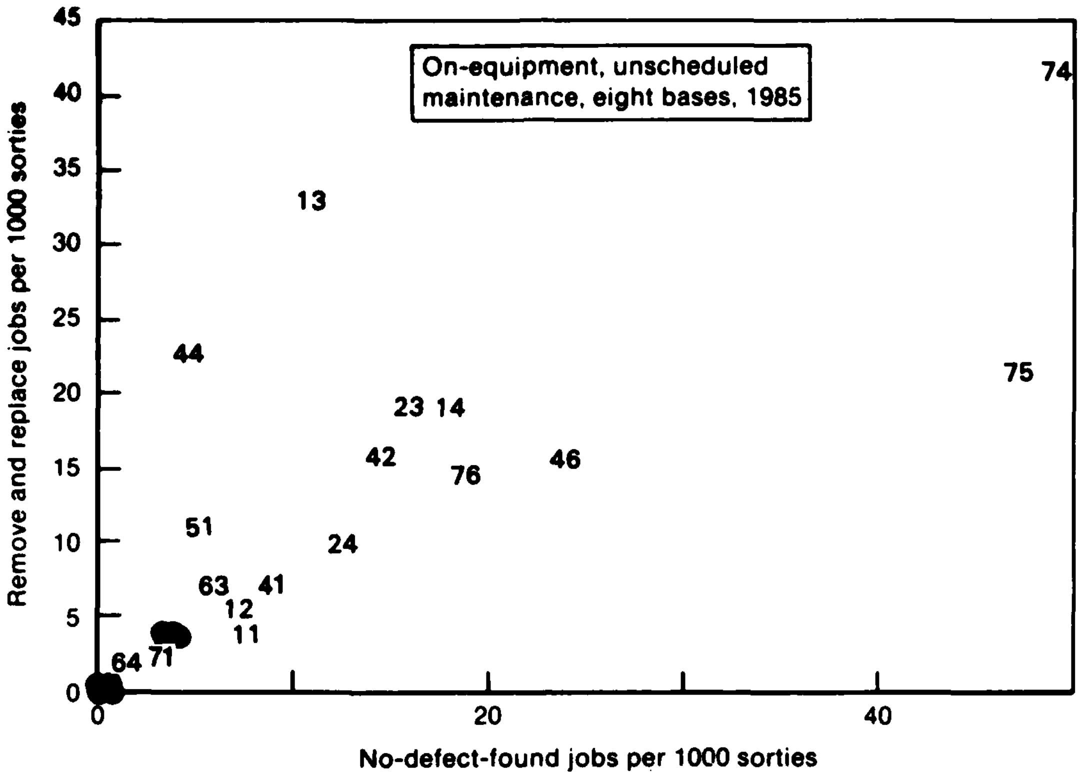

Fig. 6—Scatter diagram of remove/replace vs. no-defect-found job counts by 2-digit WUC

of R&M improvement problems. Systems plotted in between have a mix of the two different kinds of jobs. Mean time between failure, as typically prepared and used by the Air Force, counts only the remove-and-replace jobs and, of that set, only those where later shop examination confirms the failure.

Not one of the 2-digit systems plotted has exclusively remove-and-replace or exclusively no-defect-found jobs. For example, system 13 (Landing Gear) tends to have mostly remove-and-replace jobs whereas system 75 (Weapons Delivery) has a significant fraction of no-defect-found jobs. The overall ranking also shows up well in this kind of a plot, as systems with larger numbers of jobs overall are plotted up and to the right. Different kinds of displays clearly highlight different aspects of the same problem, which argues rather strongly in favor of not using one kind of display exclusively.

Select Candidates and Look at Them Closer

To proceed, we pick five 2-digit systems--the Fire Control System (WUC = 74), the Weapons Delivery System (WUC = 75), the Landing Gear System (WUC = 13), the Flight Control System (WUC = 14), and the Turbofan Power Plant (WUC = 23)--to investigate further. We stopped at this point simply to limit the size of our example. The systems are listed in decreasing order of importance as measured by the sum of remove-and-replace and no-defect-found jobs per thousand sorties. Subsequently, we will examine each of these 2-digit systems, in this order.

Table 8 presents some helpful information. The remove-and-replace jobs plus the no-defect-found jobs for the five 2-digit systems that we selected account for roughly 25 percent of all of the jobs (including minor repair and other jobs). Of all remove-and-replace and no-defect-

Table 8

POTENTIAL TARGETS FOR R&M IMPROVEMENTS
(On-equipment, unscheduled maintenance jobs
per 1000 entries, eight bases, 1985)

WUC	Aircraft System	Remove and Replace	No Defect Found	Minor Repair	Other	Total
74	Fire Control	41.55	49.21	13.67	22.67	127.1
75	Weapons Delivery	21.23	47.02	10.01	19.67	97.94
13	Landing Gear	32.76	10.73	48.93	11.81	104.23
14	Flight Controls	18.79	17.75	23.15	16.19	75.89
23	Turbofan Power Plant	19.06	15.8	15.53	15.45	65.84
Target Systems		133.39	140.51	111.29	85.79	470.98
Other Systems		132.89	130.48	224.51	187.44	675.32
Total		266.28	270.99	335.8	273.23	1146.31
Percent of Total Jobs						
Target Systems		11.64	12.26	9.71	7.48	41.09
Other Systems		11.59	11.38	19.59	16.35	58.91
Total		23.23	23.64	29.29	23.84	100.00

found jobs, about 50 percent are performed on the five selected systems. As can be seen from Table 7, the remaining 50 percent are distributed over a wide range of other aircraft systems.

In what follows, we will be trying to learn what the important R&M problems are by looking in depth at five major aircraft systems and 50 percent of all of the remove-and-replace and no-defect-found jobs.

THE FIRE CONTROL SYSTEM (FCS)

We now examine the Fire Control System at the 3-digit work unit code level. Table 9 and Fig. 7 show the number of remove-and-replace and no-defect-found jobs for that system. The Radar Set and the Inertial Navigation Set are the biggest problems. Furthermore, in each case, the jobs are divided about equally between remove-and-replace and no-defect-found jobs. The plot (see Fig. 8) shows this quite dramatically.

The FCS Radar Set

Table 10 and Fig. 9 show the number of jobs per 1000 sorties for the radar set and each of its components defined at the 4-digit work

Table 9

FIRE CONTROL SYSTEM JOB COUNTS AT THE 3-DIGIT WUC LEVEL
(On-equipment, unscheduled maintenance jobs
per 1000 sorties, eight bases, 1985)

WUC3	Subsystem	Remove and Replace	No Defect Found	Total
74A	Radar Set	15.37	19.25	34.62
74B	Head-up Display Set	4.42	3.96	8.37
74C	Computer	2.19	3.12	5.31
74D	Inertial Navigation Set	12.84	12.31	25.15
74E	Radar & E-O Display Set	4.20	3.50	7.70
74F	Target Identification Laser Set	0.00	0.01	0.01
74G	Airborne Video System	2.52	6.73	9.25
740	Fire Control System	0.00	0.33	0.33

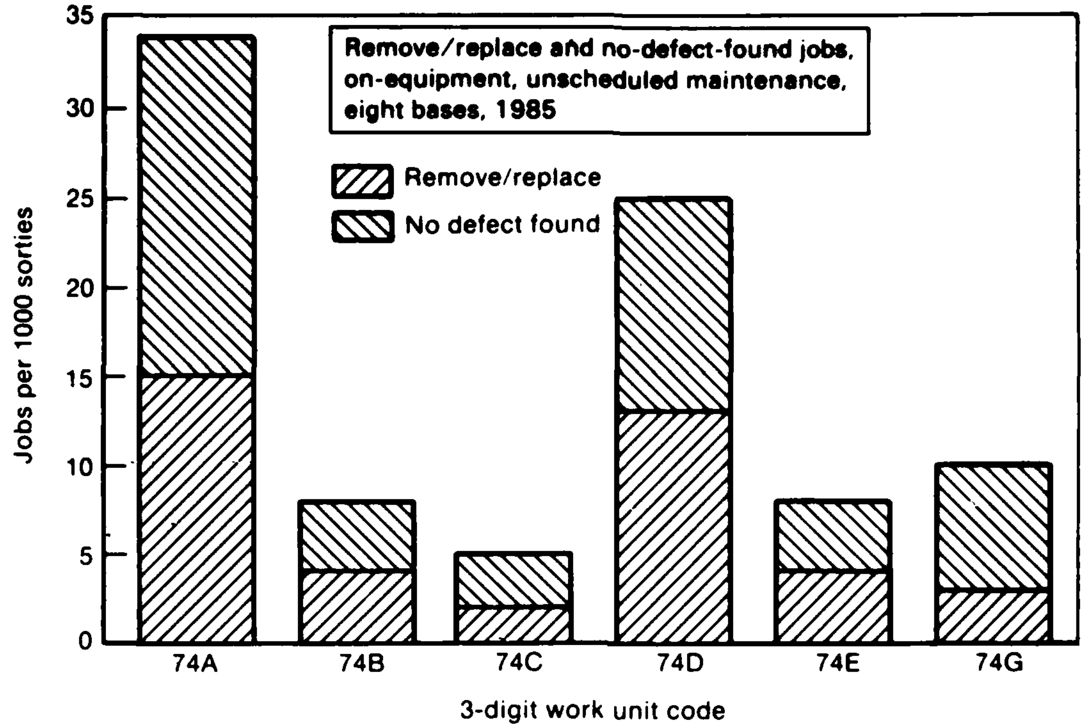

Fig. 7—Fire control system job counts at the 3-digit WUC level

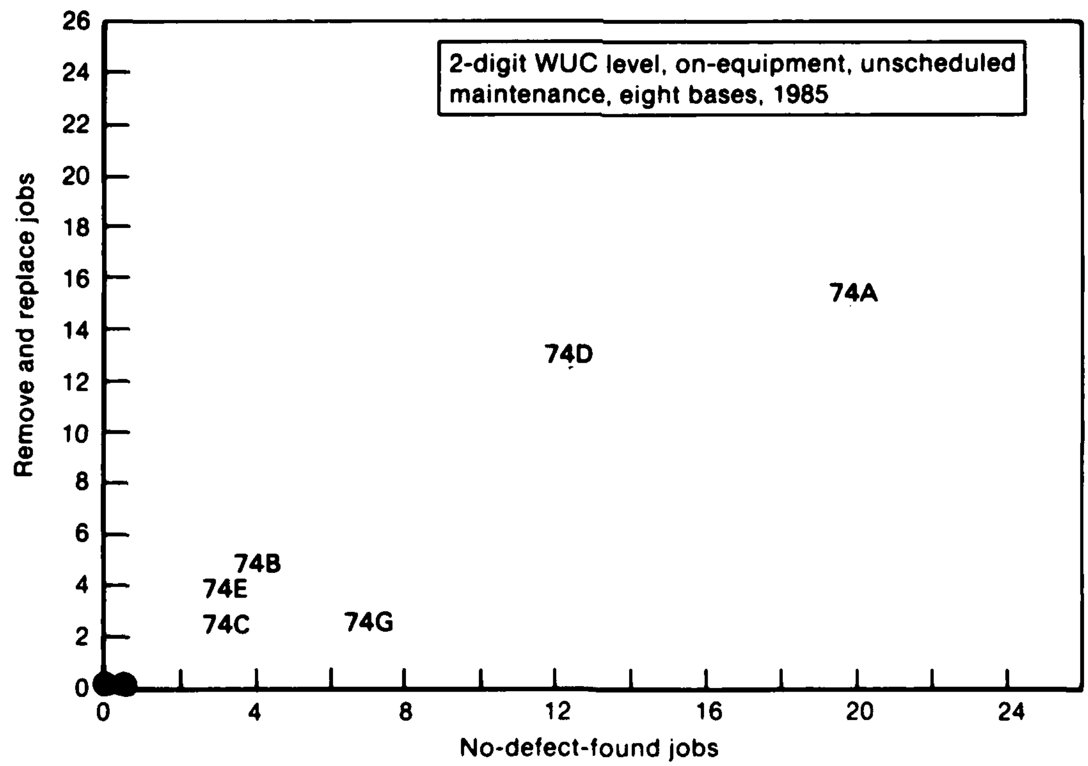

Fig. 8—Fire control system job counts, remove/replace vs. no-defect-found

unit code level. Only items having one or more jobs per 1000 sorties are included. The bad actor is system 74A0, the fire control radar set, the same one that we saw when we looked at the data by 3-digit work unit code. Also, practically all of the jobs are no-defect-found jobs. No specific component was found to be at fault. It is typical that no-defect-found jobs are not identified to specific components. If one had been identified, that component probably would have been removed and replaced and hence would not be in the no-defect-found job category.

Table 10

POTENTIAL TARGETS FOR R&M IMPROVEMENT: FIRE CONTROL SYSTEM
(On-equipment, unscheduled maintenance jobs
per 1000 sorties, eight bases, 1985)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Fire Control System Radar Set				
74A0	Fire Control Radar Set	0	17	17
74AB	Low Power RF Unit	6	1	7
74AA	Radar Antenna	2	0	2
74AC	Radar Transmitter	2	0	2
74AD	Digital Signal Processor	2	0	2
74AF	Radar Computer	2	0	2
	Total	14	18	32
Fire Control System Inertial Navigation Set				
74DA	Inertial Navigation Unit	8	2	10
74D0	Inertial Navigation Set	0	9	9
74DD	Fire Control System/Navigation Panel	3	1	4
74DB	INU Storage Battery	2	0	2
	Total	13	12	25

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

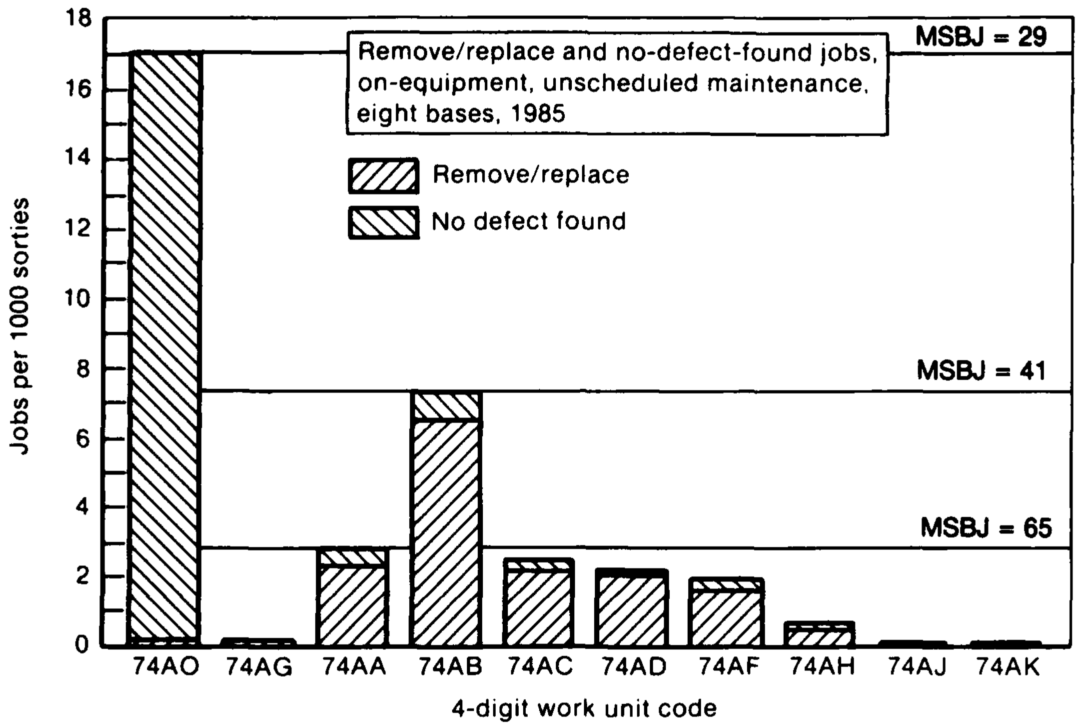

Fig. 9—Radar system job counts at the 4-digit WUC level

The Low Power RF Unit seems to dominate the remove-and-replace category of jobs. In fact, it looks as though the majority of fixes to the radar set involve replacing that unit. We believe, from some other RAND work, that Low Power RF Unit problems are the primary F-16 radar problems. The other RAND work required a special six-month contractor data collection followed by another three months to analyze the results.

FCS: Component R&M Improvements vs. Radar Set Performance

How much better off would things be if we fixed the problems identified so far? The answer is usually neither straightforward nor simple.

Given the data in Fig. 9, the Mean Sorties Between Jobs (MSBJ) for the entire radar system is approximately 29. Now suppose that we start with the 74A0 (Fire Control Radar Set), and reduce the no-defect-found jobs such that the total is equal to 7.5 jobs per 1000 sorties (same as for the 74AB the Low Power RF Unit). We would then calculate that the overall MSBJ has increased to about 41. If we continue in this way, and reduce the incidence of failure (jobs per 1000 sorties) for 74A0 and for 74AB to three jobs per 1000 sorties, we calculate that the overall MSBJ has gone up to about 65. Thus, we could more than double the MSBJ by significantly reducing the number of no-defect-found jobs and improving the reliability of the Low Power RF Unit.[1]

The FCS Inertial Navigation Set

The next largest consumer of maintenance among the subsystems of the Fire Control System is the Inertial Navigation Set. Table 10 also shows the jobs on this subsystem broken down by 4-digit WUC. Removing and replacing the Inertial Navigation Unit accounts for about one third of all the maintenance jobs, and a little more than another third is accounted for by no-defect-found jobs on the Inertial Navigation Set. Once again, there are both reliability and maintainability problems.

Observations on the Fire Control System

Thus far, our screening exercise has identified the Fire Control System as a potential candidate for R&M improvement. Furthermore, it suggests that there are two candidate subsystems: the Radar Set and the Inertial Navigation Set. We have found that the radar set is plagued by problems that are perceived but for which no specific defect can be identified. With regard to the Inertial Navigation Set, we also see a number of no-defect-found jobs and that, when a component is removed and replaced (presumably a fault has been found), it is the Inertial Navigation Unit. All of this seems to indicate that fault diagnosis, a maintainability issue, should receive primary attention to improve the R&M of the Fire Control System.

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[1]The failure index graphed in Fig. 9 is substantially higher than the mean time between confirmed failure typically calculated by the Air Force because we include no-defect-found jobs.

FCS: Possible Next Steps

It may be possible to get additional insights about the radar set and its problems by delving into the MDC data more. But we probably have done enough of that for the present and should either go back to looking for other targets of opportunity (screening) or initiate a more detailed and systematic investigation of the fire control radar system.

THE WEAPONS DELIVERY SYSTEM (WDS)

Figure 10 shows remove-and-replace and no-defect-found jobs on the Weapons Delivery System broken down by 3-digit work unit code. The Weapons Rack subsystem (Code 75C) and the Stores Management subsystem (Code 75D) stand out as the most troublesome subsystems. Together these subsystems account for about 80 percent of all jobs on the Weapons Delivery System.

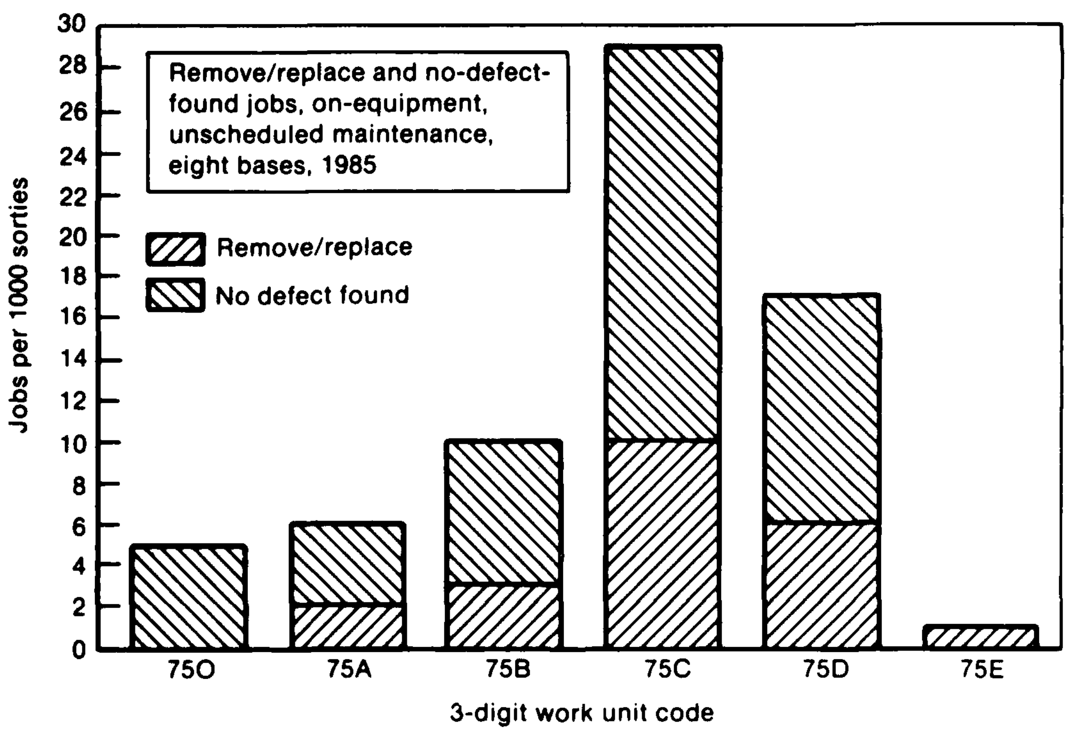

Fig. 10—Weapon delivery system job counts at the 3-digit WUC level

Table 11 presents a 4-digit work unit code breakout for each subsystem. About two thirds of the jobs for each subsystem are no-defect-found jobs. It looks like another fault isolation, fault diagnosis, or maintenance problem.

Table 11

POTENTIAL TARGETS FOR R&M IMPROVEMENT: WEAPONS DELIVERY SYSTEM
(On-equipment, unscheduled maintenance jobs per 1000 sorties, eight bases, 1985)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Weapons Rack System				
75CB	Wingtip Launcher	4	6	10
75CJ	SUU-20B/A Bomb Dispenser	1	4	5
75C0	Weapon Rack System	2	2	4
75CK	TER-9/A Ejector Rack	1	3	4
75CA	Underwing Launcher	0	2	2
75CH	LAU-88 Missile Launcher	0	1	1
75C9	Weapon Rack System Not Otherwise Coded	1	0	1
	Total	9	18	27
Stores Management System				
75D0	Stores Management System	1	5	6
75DC	Central Stores Interface Unit	3	3	6
75DA	Stores Control Panel	0	1	1
75DD	Jettison/Release Remote Interface Unit	1	0	1
75DF	Nuclear Remote Interface Unit	0	1	1
75D9	Stores Management System Not Otherwise Coded	0	1	1
	Total	5	11	16

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

WDS: The Weapons Rack System

The single biggest problem in the Weapons Rack System appears to be the Wingtip Launcher, with 60 percent of the jobs being no-defect-found. The next largest problems are with the SUU-20B/A Bomb Dispenser and the TER-9/A Ejector Rack. Combined, they are equal to the Wingtip Launcher. No other component stands out. To maintain perspective, note that these three subsystems or components account for roughly two thirds of the jobs on the Weapons Rack System.

WDS: Stores Management System

Among the Stores Management System subsystems only the Central Stores Management Interface Unit (75DC) stands out. It alone accounts for about 40 percent of the jobs, split roughly 50-50 between no-defect-found and remove-and-replace jobs. Another 40 percent of the jobs are no-defect-found jobs that have been attributed only to the Stores Management System itself.

WDS: Observations

Thus, we see the Weapons Delivery System problem as follows: About two thirds reliability and one third maintainability. Further investigation of the Weapons Rack System should be focused on the Wingtip Launcher, the Bomb Dispenser, and the Ejector Rack, and probably in that order. On the Stores Management System, further investigation might be focused on the Interface Unit but more likely on the whole system and the general problem of fault isolation and problem diagnosis.

THE LANDING GEAR SYSTEM

The Landing Gear System is next in order of the number of jobs performed. As indicated in Fig. 11, 60 percent of the jobs are performed on subsystem 13D, Wheels and Tires, and on subsystem 13E, the Brake and Skid Control System. It also appears, from the preponderance of remove-and-replace jobs, that when a problem is discovered, it is fixable. See Table 12.

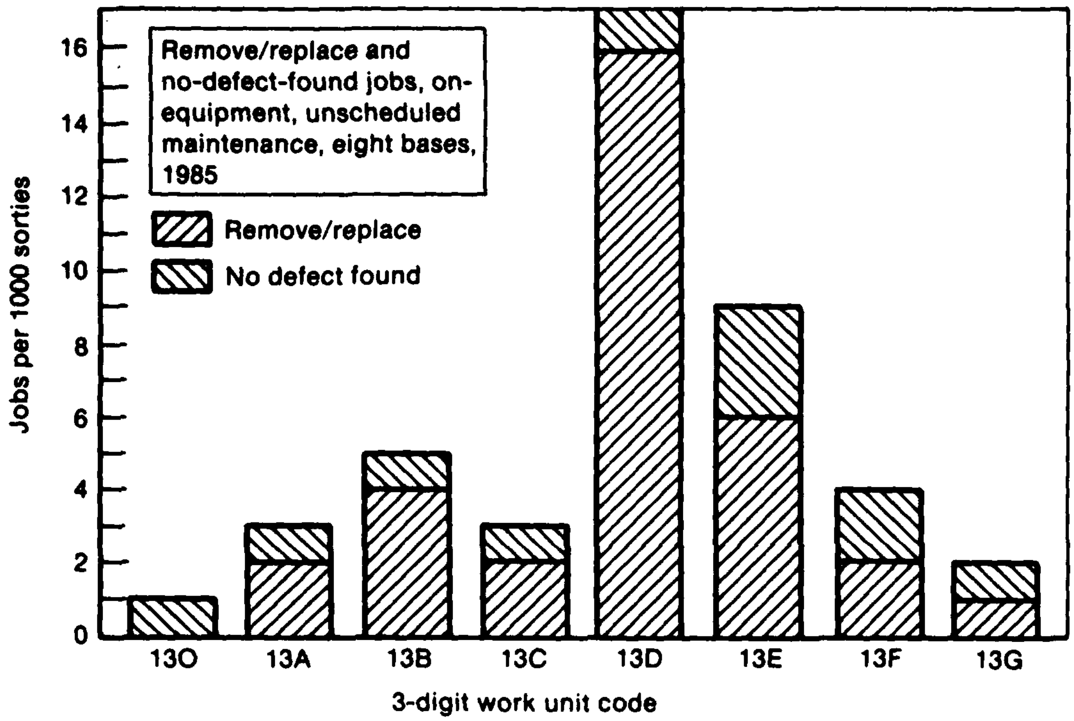

Fig. 11—Landing gear system job counts at the 3-digit WUC level

Table 12

POTENTIAL TARGETS FOR R&M IMPROVEMENT: LANDING GEAR SYSTEM
(On-equipment, unscheduled maintenance jobs
per 1000 sorties, eight bases, 1985)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Wheels and Tires				
13DA	Main Landing Gear Wheel/Tire Assembly	11	0	11
13DB	Nose Landing Gear Wheel/Tire Assembly	4	0	4
	Total	15	0	15
Brake and Skid Control System				
13E0	Brake and Skid Control System	6	3	9

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

THE FLIGHT CONTROL SYSTEM

The maintenance activity on the subsystems of the Flight Control System is shown in Fig. 12. The Primary Flight Control Electronics (WUC = 14A) generates the largest number of jobs and the Air Data System (WUC = 14F) is next. Even though these subsystems generate more maintenance than any of the other subsystems, they only generate 12 and six jobs per thousand sorties respectively. These are very small numbers.

Is the Number of Jobs Significant?

Another way to perceive the frequency of occurrence of these jobs is to picture being at an operating base of 100 F-16 A/Bs, say Hill AFB, and counting these jobs as they occur. You might expect to count (on average) a total of 1.8 jobs on the Flight Control System Electronics and the Air Data System on each of the 250 flying days during a normal

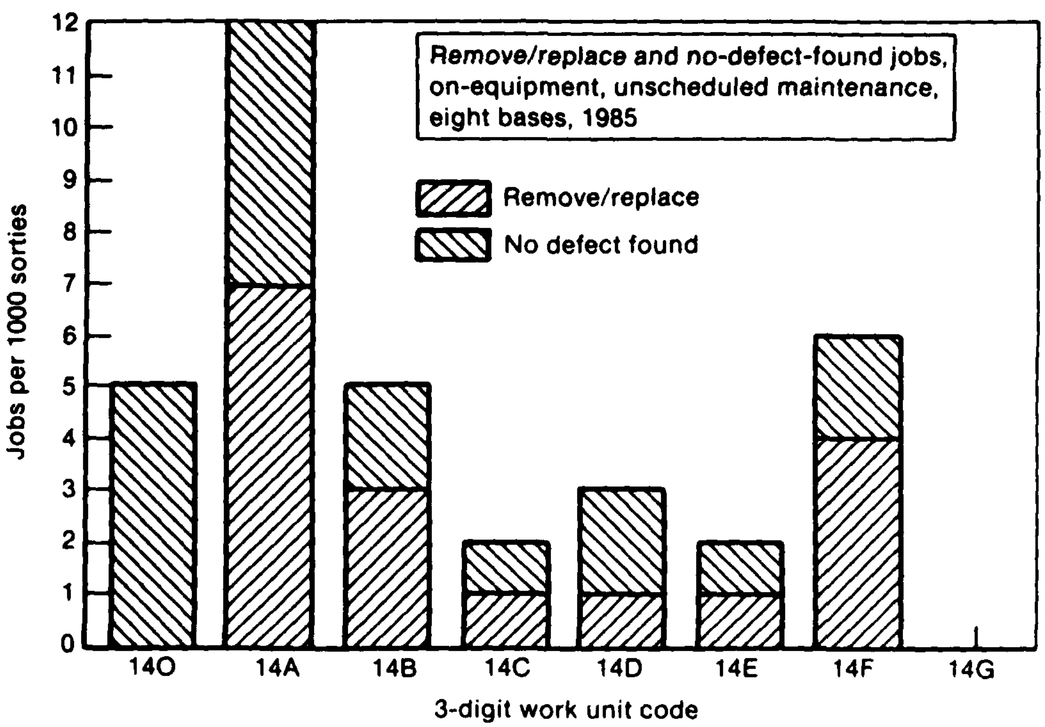

Fig. 12—Flight control system job counts at the 3-digit WUC level

year. (Each aircraft, on average, flies one sortie per day; and there are approximately 250 flying days per year.) Perhaps in wartime, with double or triple the peacetime sortie rate you might count as many as 5.4 of these jobs per day. These jobs are sufficiently likely to be considered of interest.

Flight Control System: Observations

By looking at the 4-digit work unit code breakdown for these two systems, we see from Table 13 that almost half of the Flight Control Electronics jobs and one quarter of the Air Data System jobs are no-defect-found jobs.

Table 13

POTENTIAL TARGETS FOR R&M IMPROVEMENT: FLIGHT CONTROL SYSTEM
(On-equipment, unscheduled maintenance jobs
per 1000 sorties, eight bases, 1985)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Primary	Flight Control Electronics			
14A0	Primary Flight Control Electronics	0	4	4
14AA	Flight Control Computer Assembly	2	1	3
14AB	Stick Controller Assembly	1	0	1
14AD	Flight Control Panel Assembly	1	0	1
14AG	Flight Control Rate Gyro Assembly	1	0	1
	Total	5	5	10
Air Data System				
14FB	Electronic Component Assembly	2	0	2
14F0	Air Data System	0	1	1
14FD	Angle of Attack Transmitter	1	0	1
	Total	3	1	4

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

With regard to the Flight Control Electronics, no single subsystem or component stands out. The Computer Assembly (WUC4 = 14AA) does show two remove-and-replace jobs and one no-defect-found job. The no-defect-found jobs are, as expected, not identifiable to any single subsystem or component. The data on the Air Data System suggest little that might be of help.

Other than serving to indicate that the Flight Control System is a possible candidate for R&M improvement and that much of the problem is still fault isolation and problem diagnosis, the MDC data provide nothing more that helps to either clarify the problem or focus further investigations. Some field work is clearly in order.

THE TURBOFAN POWER PLANT

We now turn to the Turbofan Power Plant (see Fig. 13 and Table 14). System 231 (Instruments, Controls, and Mounting System) shows the single largest number of jobs. One quarter of these are no-defect-found jobs. Next largest is system 23Z (the Assembled Engine), and no further breakdown is possible with the MDC data. The jobs on this system are split roughly half and half between remove-and-replace and no-defect-found. System 230 (the Whole Power Plant, which includes the assembled engine and all of the accessories) is next; 80 percent of these jobs are again no-defect-found. As with 23Z, the data permit no further breakdown.

The Augmentor Duct and Nozzle Module (WUC3 = 23F) also account for a large number of jobs. Roughly 60 percent are remove-and-replace jobs. And the single largest number of those jobs is to remove-and-replace the Divergent Nozzle Segment Seal, WUC = 23FBA. We went to the 5-digit work unit code level to identify the nozzle.

We did the same thing for the Fuel System and observed that three components emerge: the Engine Electronic Control (WUC = 23HAB), the Main Fuel Pump (WUC = 23HAD), and a Turbine Inlet Temperature Sensor (WUC = 23HAK). Of the three jobs accounted for by these components, two of them were no-defect-found jobs.

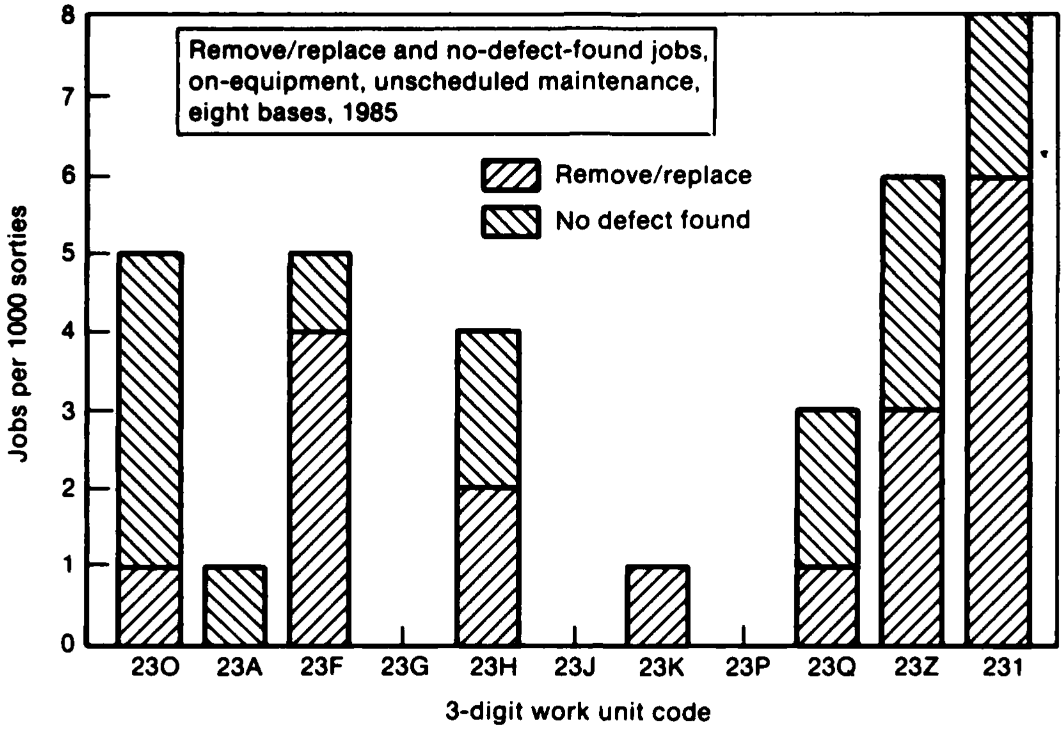

Fig. 13—Turbofan power plant system job counts at the 3-digit WUC level

Table 14

POTENTIAL TARGETS FOR R&M IMPROVEMENT: TURBOFAN POWER PLANT
(On-equipment, unscheduled maintenance jobs
per 1000 sorties, eight bases, 1985)

WUC	Subsystem	Remove and Replace	No Defect Found	Total
Engine Instruments, Controls, & Mounting System				
231A	Engine Instruments	3	0	3
231B	Power Booster Control Rack Assembly	2	1	3
2310	Engine Instruments, Controls & Mounting System	0	1	1
	Total	5	2	7
Augmentor Duct and Nozzle Module				
23FBA	Divergent Nozzle Segment Seal	3	0	3
Fuel System				
23HAB	Engine Electronic Control	0	0	1
23HAD	Main Fuel Pump	0	1	1
23HAK	Fan Turbine Inlet Temperature Sensor	0	1	1
	Total	3	2	6

NOTE: Subsystems or components with less than one job per 1000 sorties are not shown.

OVERVIEW AND NEXT STEPS

We have observed an inordinately large number of maintainability problems. Reliability, in terms of components clearly breaking or otherwise failing, seems almost secondary. Apparently, pilots and ground crews are frequently able to observe faulty or degraded system performance, but the maintenance people are unable to relate that information to a fixable problem.

It is impossible to tell, from these data alone, whether nonexistent problems are being reported to maintenance or whether the reported problems are real and the fault is with maintenance. Determining which is an important next step. Certainly a lot of maintenance manpower is being expended with little or no apparent benefits.

Table 15 presents one summary of our findings. The five major systems that we investigated are presented in decreasing order of importance. Importance is measured by the sum of remove-and-replace and no-defect-found jobs performed per 1000 sorties. Those subsystems and/or components receiving more maintenance attention than any others are also noted.

The two right-hand columns in the table indicate whether the problem with a particular system, subsystem, or component is a reliability or a maintainability problem or some of each. The scale, which is self explanatory, is purposely crude because all we wish to convey are general impressions.

Many of the systems listed are clearly important R&M problems, the Fire Control System for example. Others are more questionable. Our primary basis for choosing these systems was that they received a lot of the kinds of maintenance attention we believe indicate R&M problems. Other insights should certainly be brought to bear on the selection of those to pursue further.

Suppose the Weapons Delivery System is chosen for more in-depth analysis and site visits to F-16 A/B bases are being set up. One should be prepared to discuss the Weapons Rack System and the Stores Management System at some length. Discussions of the Weapons Rack System should probably begin by discussing the Wingtip Launcher, the Bomb Dispenser,

Table 15

POTENTIAL TARGETS FOR R&M IMPROVEMENT,
SUMMARY OF SCREENING RESULTS

WUC	System	Reliability Problem	Maintainability Problem
74	Fire Control System	<Half	>Half
74A	Radar Set	<Half	>Half
74AB	Low Power RF Unit	Mostly	Some
74D	Inertial Navigation Set	Half	Half
74DA	Inertial Navigation Unit	Mostly	Some
74DD	Fire Control/Navigation Panel	Mostly	Some
75	Weapons Delivery System	Some	Mostly
75C	Weapons Rack System	Some	Mostly
75CB	Wingtip Launcher	<Half	>Half
75CJ	SUU-20B/A Bomb Dispenser	Some	Mostly
75CK	TER-9/A Ejector Rack	Some	Mostly
75D	Stores Management System	Some	Mostly
75DC	Central Stores Interface Unit	Half	Half
13	Landing Gear System	Mostly	Some
13D	Wheels and Tires	Mostly	Some
13DA	MLG Wheel/Tire Assembly	All	None
13DB	NLG Wheel/Tire Assembly	All	None
13E	Brake and Skid Control System	Mostly	Some
14	Flight Control System	Half	Half
14A	Primary Flight Control Electronics	>Half	<Half
14AA	Flight Control Computer Assembly	Mostly	Some
14F	Air Data System	Mostly	Some
14FB	Electronic Component Assembly	All	None
23	Turbofan Power Plant	>Half	<Half
231	Engine Instruments, Controls etc.	Mostly	Some
231A	Engine Instruments	All	None
231B	Power Booster Control Rack Assembly	Mostly	Some
23F	Augmentor Duct & Nozzle Module	Mostly	Some
23FBA	Divergent Nozzle Segment Seal	All	None
23H	Fuel System	Half	Half

and Ejector Rack. Also ask about the large number of no-defect-found jobs. With regard to the Stores Management System, start out by asking about the Central Stores Interface Unit. Once again, try to find out why there are so many no-defect-found jobs.

The above is just for openers. Other issues will come up and may well be more important. The whole screening process that we have just been through is simply a way to organize the investigation.

IV. VARIABILITY IN THE DATA BASE

Screening, in the previous section, was done using worldwide averages (totals) for the entire F-16 A/B fleet. In the real world the investigation should obviously be concerned with variation among bases and over time as well. It would be nice if each base was truly represented by the average but, as is often the case, life is not so simple. In fact, the variation among the eight bases, with ostensibly similar aircraft, is quite large. Here we indicate the extent of this variability and provide some limited insights into why the variation is so large.

VARIABILITY AMONG BASES

Figure 14 shows the number of maintenance actions per 1000 sorties recorded for each of the eight F-16 A/B bases in the calendar years 1984 and 1985. These are the number of records (lines on form DD349s) for each base in the Bases File. Remember, the Bases File includes all on-equipment (on-aircraft) unscheduled maintenance. It also includes the fix phase of phased inspection.

After all our efforts at defining and counting "Jobs," why are we now counting maintenance actions? The main reason is to prepare ourselves for making some site visits to find out why there are differences. It would be easiest to communicate with people at the operating level if we could talk directly in terms of maintenance actions rather than jobs. And, furthermore, we noted that maintenance actions and jobs are highly correlated.

The differences among the bases is clearly significant. MacDill reported about 3000 maintenance actions per 1000 sorties; Hahn and Kunsan reported about one half of that amount. The year to year variation is much less. Nellis is the only base that reported more activity in 1984 than in 1985.

The eight bases divide into three groups. Luke and MacDill, the two pilot training bases, report the most activity; Hahn, Torrejon, and Kunsan, the three overseas bases, report the least. Hill, Nellis, and

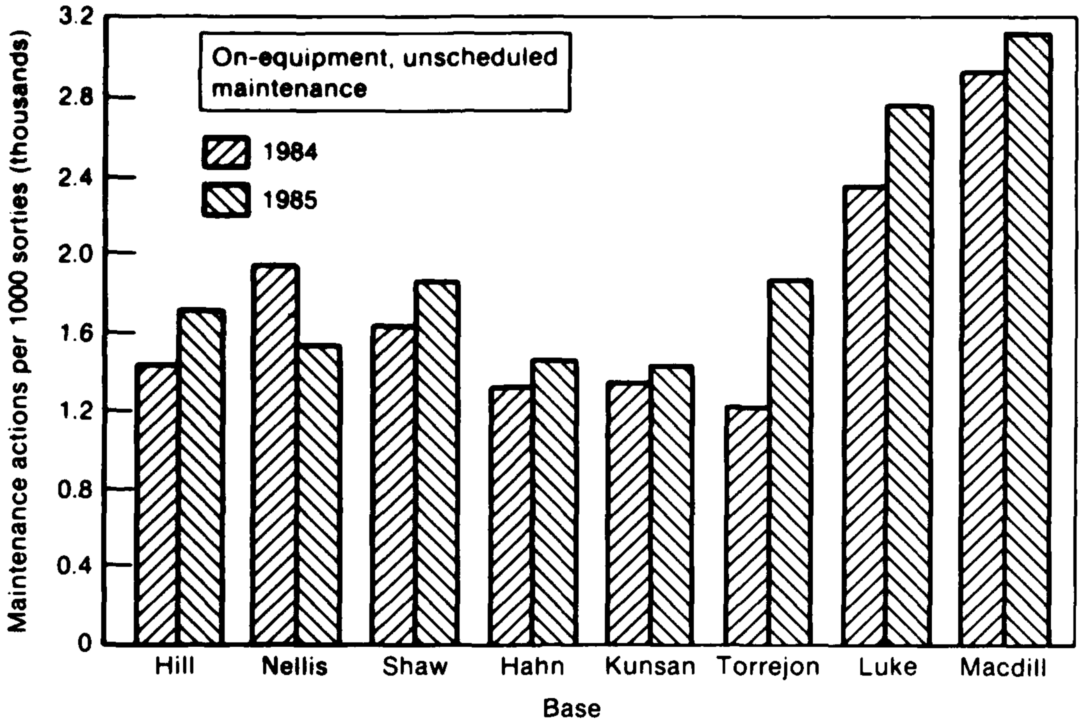

Fig. 14—Distribution of maintenance actions among bases: 1984 and 1985

Shaw, the three CONUS operational bases, report slightly more than the overseas bases but nothing like the amount reported by the training bases.

Figure 15 presents a somewhat different view of the interbase variability. There the focus is on the variability among bases for each two-digit work unit code. The lower end of each bar shows the number of maintenance actions per 1000 sorties for the base that reported the fewest. The upper end of each bar indicates the number of maintenance actions per 1000 sorties for the base that reported the most. You can't tell which bases those were from the figure. Finally, the diamond in between the two extremes indicates the average over all eight bases.

For example, the bar for two-digit work unit code 11 (Airframe) indicates that at least one of the eight bases reported about 1000 maintenance actions per 1000 sorties while at least one other reported

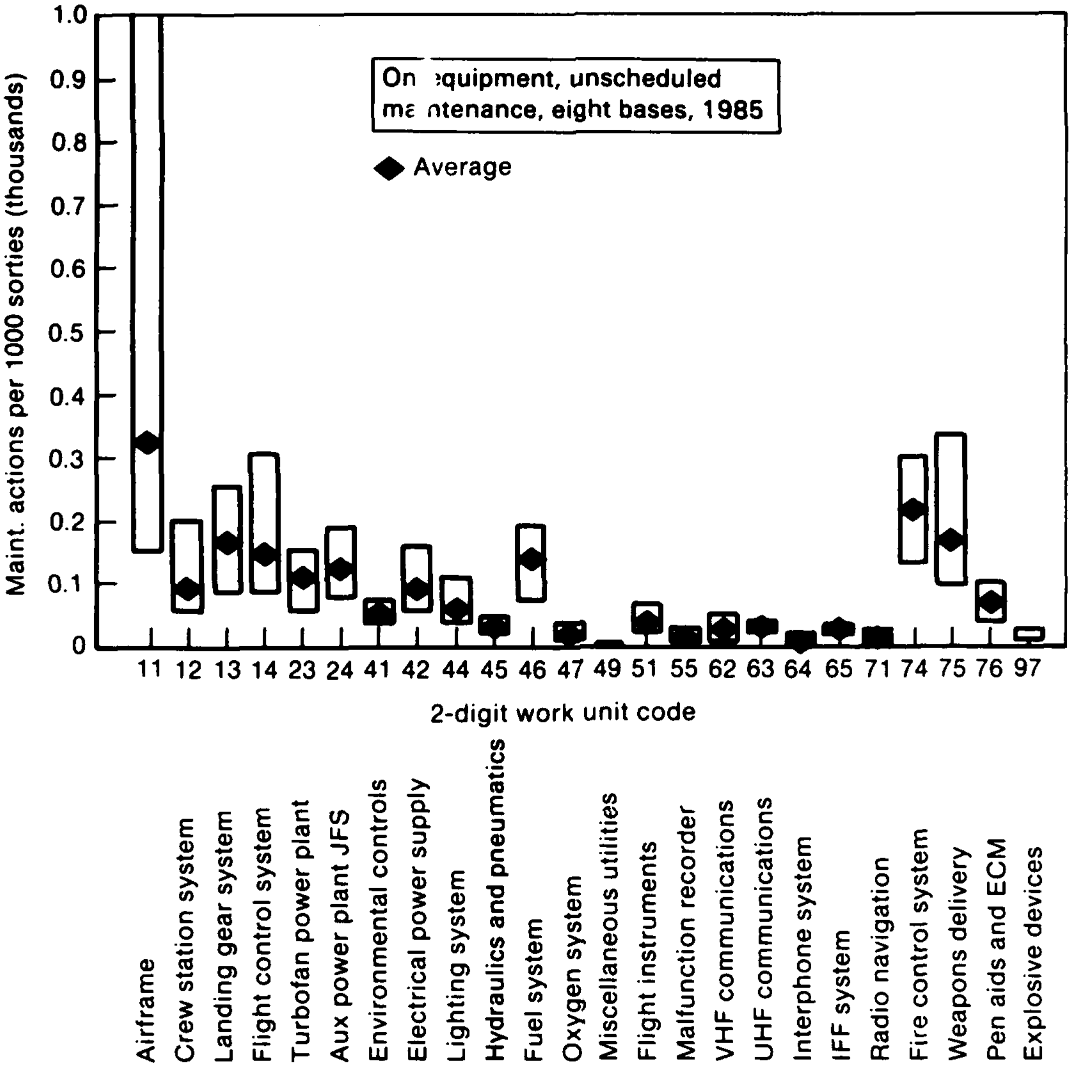

Fig. 15—Range of maintenance actions across eight bases at the 2-digit WUC level: minimum, maximum, and average

only 150. The average over all of the bases was roughly 320. Because the average is much closer to the lower extreme, one can conclude that the upper extreme, and hence much of the range, is accounted for by one or two bases.

RESEARCH TO EXPLAIN THE INTERBASE VARIABILITY

Is all of this variation real or is it simply reflecting errors in reporting? If the variation is real, how do we deal with it in our attempt to identify candidates for R&M improvement? Many people with some knowledge of the MDC suggest that the data are, for the most part, next to worthless. They cite different local policies about what and how to report maintenance activities, different incentives for reporting maintenance activities, and just plain sloppiness as the main reasons. Unfortunately, we were unable to find much more than anecdotal evidence to support these claims and so we undertook a small research task to see for ourselves.

Our plan was to choose a couple of bases, to show the maintenance people at each of those bases their reported maintenance actions, and to ask why they were so different from each other. We selected Hill and Luke for this experiment because they characterized the two extremes quite well (see Fig. 14). Only one base, MacDill, reported more maintenance activity than Luke. And Hill, while not the lowest, was sufficiently close to the low end of the spectrum to characterize that extreme. The results, described below, were obtained during two one-day visits. We visited Luke first and then Hill.

Figure 16 and Table 16 are two of the more useful displays that we prepared from the MDC data in preparation for these visits. Figure 16 is a plot of the maintenance actions per 1000 sorties for Luke against those for Hill by two-digit work unit code. If the numbers reported from each base were the same, all of the points would have been plotted on a 45 degree line running through the origin. In virtually every instance the points are well above that line. Thus, for almost every two-digit work unit code, Luke reported more maintenance activity than did Hill.

Table 16 illustrates the primary material that we used to guide our interviews. The number of maintenance actions per 1000 sorties were counted for each base and for each four-digit work unit code. The number for Hill was subtracted from the number for Luke and the entire list was sorted on the difference--largest difference first etc. We simply started at the top of the list and attempted to discuss each line item in turn.

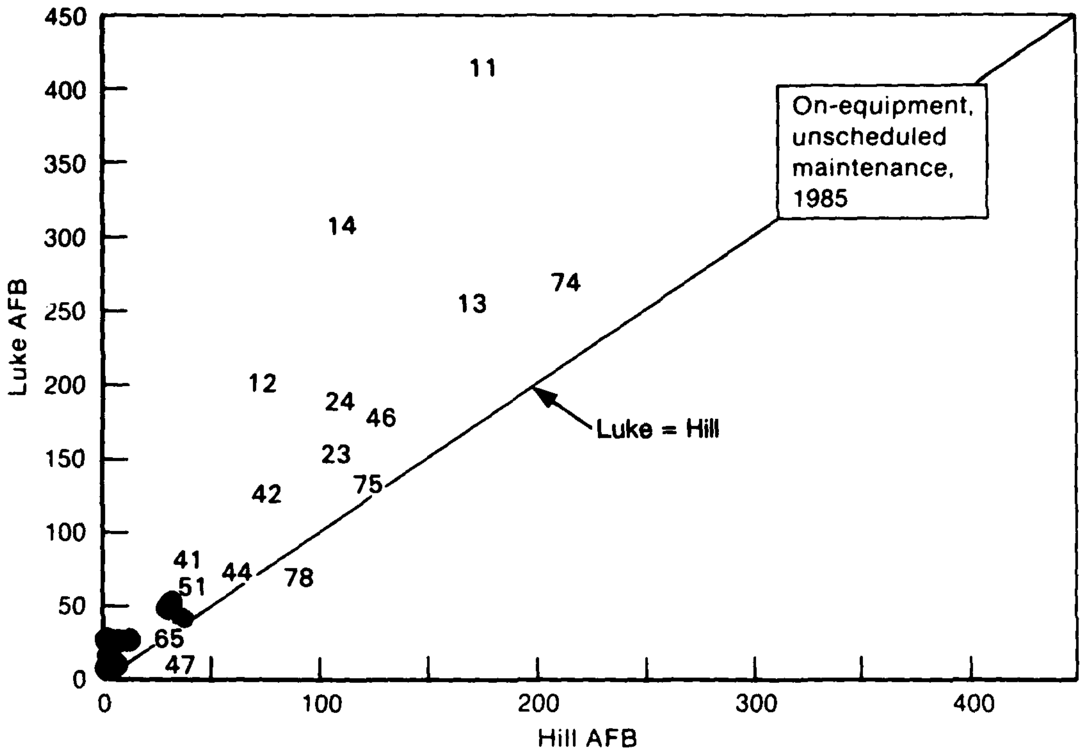

Fig. 16—Comparison of Luke and Hill AFB maintenance actions per 1000 sorties by 2-digit WUC

RESEARCH RESULTS

The entire effort depended on our being able to identify people in the base level maintenance shop who were involved in the particular jobs of interest and on their recollection of the circumstances surrounding that activity. We were able to accomplish this for only eight of the items on the list. An asterisk on the list indicates which items these were.

Airborne Video Tape Recorder

The first item on the list is the Airborne Video Tape Recorder (WUC4 = 74GB). Luke reported 73 maintenance actions per 1000 sorties against this system while Hill reported only 11--a very large difference indeed. Luke is a pilot training base and the video tape recorder is an essential instrument of this training. The recorder operates every

Table 16

COMPARISON OF HILL AFB AND LUKE AFB MAINTENANCE ACTIONS
BY 4-DIGIT WUC
(On-equipment, unscheduled maintenance per
1000 sorties, 1985)

Work Unit Code		System/Subsystem	Hill AFB	Luke AFB	Diff.	Cum. Diff.	Cum. Pct.
74GB	*	RECORDER A-B VD TP	11.3	72.8	61.5	61.5	4.5
12CA	*	CANOPY ASSEMBLY	17.6	62.7	45.1	106.6	7.8
11GD	*	LOWER DOORS & COVERS	14.0	58.0	44.0	150.6	11.0
1100		AIRFRAME	3.0	36.4	33.4	184.0	13.5
13EA		BRAKE & SKID CONTROL	15.7	36.0	20.4	204.4	15.0
46DA	*	TANK WING	8.0	27.6	19.6	224.0	16.4
14A0		PRIMARY FLT CONTROL	15.4	34.9	19.4	243.5	17.8
12EG		PARACHUTE ASSEMBLY	0.0	19.0	19.0	262.4	19.2
11GE	*	UPPER DOORS & COVERS	8.2	26.7	18.5	280.9	20.6
13DA	*	MAIN GEAR WHEEL/TIRE	10.7	27.7	17.1	298.0	21.8
46DE	*	TANK AFT A-1	3.7	20.3	16.6	314.6	23.0
1400		FLIGHT CONTROL SYSTE	11.6	26.6	15.0	329.5	24.1
11EE		UPPER DOORS & COVERS	11.5	25.8	14.3	343.8	25.2
11ED		LOWER DOORS & COVERS	32.6	46.9	14.3	358.1	26.2
11GA		STRUCTURE	4.6	18.4	13.9	372.0	27.3
14CB		HORIZONTAL STABILIZE	6.7	20.2	13.4	385.4	28.2
12E0	*	EJECTION SEAT	37.5	50.9	13.4	398.8	29.2
24A0		EPU POWER SECTION	4.1	17.2	13.1	411.9	30.2
.		.	.	.	.	.	.
.		.	.	.	.	.	.
.		.	.	.	.	.	.
.		.	.	.	.	.	.
46F0		FUEL TANKS EXTERNAL	8.7	3.2	-5.5	-160.6	52.8
13GA		ARRESTING GEAR	9.6	3.9	-5.7	-166.3	54.7
42GA		BATTERY AIRCRAFT	19.3	13.6	-5.7	-172.0	56.5
76EE		RECEIVER CONTR FSRS	12.3	6.4	-5.9	-177.9	58.5
13CA		MECHANICAL COMPONENT	14.0	8.0	-6.0	-183.9	60.4
23Z0		ASSEMBLED TURBO FAN	38.9	32.3	-6.6	-190.5	62.6
76EG		SIGNAL PROCESSER	12.3	5.5	-6.8	-197.3	64.9
76E0		RAD THREAT WARN SET	31.0	23.7	-7.3	-204.6	67.3
13BA		MECHANICAL COMPONENT	25.3	17.7	-7.6	-212.3	69.8
47AA		COMPONENTS	10.7	2.5	-8.2	-220.5	72.5
23HA		COMPONENTS	16.3	7.5	-8.8	-229.3	75.4
47AD		REGULTOR OXY BRTHNG	12.6	3.4	-9.2	-238.5	78.4
24AB		GAS GEN EMER PWR UNI	38.2	26.6	-11.7	-250.2	82.2
74A0		FIRE CONT RADAR SET	41.4	26.4	-15.0	-265.2	87.2
74D0		INERTIAL NAVIG SET	27.8	10.3	-17.5	-282.7	92.9
7500		WEAPONS DELIVERY	23.3	1.7	-21.6	-304.3	100.0

* indicates those systems/subsystems covered in survey.

minute of every training flight to record the students' actions. Immediately on return from a flight, the film is removed and analyzed in detail with the student. It is extremely important that the recorder be in top operating condition at all times.

Luke is located in the desert and frequent blowing dust causes much trouble for the video tape recorder. The most severe problem seemed to be that the recording heads get dirty and need cleaning. The dirt and dust probably cause other problems as well. However, the bottom line is that the DCM instituted a local policy requiring that each recorder be removed from each aircraft for servicing every 30 days. Removals resulting from that policy alone account for most of the difference in maintenance activity between the two bases.

One might reasonably argue that such an activity should be charged to some form of service and/or inspection activity rather than to unscheduled maintenance. However, it was not. Here is one example of how a local DCM policy can profoundly influence the local maintenance activity, hence the MDC data.

Canopy Assembly and Ejection Seat

The next item on the list that we were able to check is the Canopy Assembly (WUC4 = 12CA). Also, because they seemed to be so intimately related, we will discuss the Ejection Seat (WUC4 = 12E0) at the same time. Luke reported 63 maintenance actions per 1000 sorties against the canopy assembly and another 51 against the ejection seat. Hill reported only 18 and 38 for these same two systems. This time the story is quite different.

The F-16 A/B aircraft at Hill are new block 15 aircraft. The aircraft at Luke are much older. Roughly 60 percent of Luke's F-16 A/B fleet consists of block 1 aircraft and the other 40 percent are block 5. Block number is used here only to indicate relative age not actual aircraft configuration. Many of the older F-16s have been upgraded in many ways. However, none of the upgrades are relevant to this story. The Luke aircraft were quite recently transferred there from Hill.

Shortly after receiving the aircraft from Hill, the Luke people began to observe bubbles forming in the canopy transparencies. The transparencies were delaminating. People at Hill told us later that they had seen the onset of this problem. The high temperature on the ramp at Luke was cited as one possible reason for the problem. However, there was much disagreement and the cause is not really relevant here. Technical representatives from General Dynamics were called in and the problem was eventually solved. The point is that the solution required an inordinately large number of canopy removals, which account for a large part of the differential maintenance activity.

Shortly after the aircraft arrived at Luke from Hill, a Time Compliance Tech Order (TCTO) requiring a cockpit inventory came due. Every so many months, equipment in the cockpit has to be inventoried, particularly the explosive devices. Each new inventory usually consists of simply updating the previous one, and that is not an enormous task. In this case, however, either Hill had not kept the inventory up to date, or the records got lost in the transfer of the aircraft, or something else happened.

Luke did not have the benefit of an inventory and had to start from scratch to prepare a new one. Many more canopy removals were necessary. Thus, there is a second reason for the large difference between the maintenance actions reported against the canopy by Luke and Hill. Here the underlying reason was simply the aircraft age and the related requirement for the inventory. One would not expect something like this to happen at Luke the next time the inventory is required. The important lesson to learn from this experience is that maintenance requirements on a particular system can change over time even at the same base. In fact, in this case, we might have an example of something that would only happen once--at least with this magnitude.

We are still not done with the canopy system however. During 1985, a TCTO on the Ejection Seat Sequencer came due on the Luke aircraft and, of course, not on those at Hill AFB. Implementing that TCTO required still more canopy removals. At this point most of the difference seems to have been accounted for.

Doors and Covers

The story about the Lower Doors and Covers and Upper Doors and Covers (WUC4 = 11GD and WUC4 = 11GE) was still different. Luke reported 85 maintenance actions per 1000 sorties on these two systems while Hill reported only 22.

First, the Jet Fuel Starter (JFS) doors on the Luke aircraft were found to be cracked and they had to be replaced, resulting in many door removals and replacements. This was not required for the newer Hill aircraft. Also, during 1985 the Luke people had to implement a TCTO requiring the installation of new gun doors on all of their aircraft. These two items are thought to account for most of the difference.

Again, aircraft age seems to be the culprit. From the R&M point of view, one would not expect Luke to replace cracked JFS doors next year or possibly ever. A similar statement could be made regarding the gun doors. Consequently, we might not want to inadvertently consider implementing a R&M improvement program for either JFS or gun doors based only on the observation that a lot of maintenance activity was reported on those two systems. The only way to prevent it would be to acquire insights beyond those provided by MDC alone. How do we acquire such insights? Perhaps in exactly the same way that we did here. Perhaps in a more extensive investigation.

Fuel Tanks

The Wing Tank (WUC4 = 46DA) and the Aft Tank (WUC4 = 46DE) were considered next. Luke reported 48 maintenance actions per 1000 sorties for the two systems. Hill reported only 12. When the Luke people received the aircraft from Hill they soon noted that the tanks were leaking. The main cause was the rivets or fasteners holding the tanks together. The Hill people later stated that the problem started shortly before the aircraft left Hill.

We heard a long story about how the original fasteners had been undersized and that they had, at one time, been replaced by oversized fasteners and that that was only a temporary fix, etc. At any rate, Luke was confronted with a problem that had to be solved, and Hill was not confronted with the same problem. The result was again lots more maintenance activity reported from Luke. Once more, one should not expect this kind of activity to be recurring. The Luke people did point out that not all of the work on the fuel tanks was completed in 1985 and that it was still going on in 1986.

Main Landing Gear Wheels and Tires

The Main Landing Gear Wheel and Tire (WUC4 = 13DA) is the final system that we examined. A somewhat different story emerged. Luke reported 28 maintenance actions per 1000 sorties. Hill reported 11. It seems that during the year the Air Force procured and delivered to Luke a different brand of tires. And the new tires were deficient.

Hill had the same problem, but being collocated with the Air Logistics Center, they had ready access to a supply of the older tires and hence did not have to rely completely on the new ones. Luke was not so fortunate. They could not even draw the original tires from their WRSK. A training wing is not provided with a WRSK. Thus, the Luke people did a lot of tire changing.

Furthermore, the DCM at Luke wanted to be very sure that none of his student pilots encountered tire problems on landing. For that reason, he insisted on using wet weather tire change criteria all year round and this exacerbated the problem even more.

Here we see a mix of causes for the additional work at Luke. The effect of the different brand of tires would have been difficult to forecast at best. We certainly would not expect to have a similar problem very often. The choice of tire change criteria is another instance of a DCM exercising a local policy option. In neither case could we have inferred what was going on from the MDC data alone.

OBSERVATIONS ON VARIABILITY

Although most of the above insights were gained from a short visit to Luke, we did later present our findings to the people at Hill. In several of the cases they were aware of the problems and said yes, that is the way it was. In the other cases, they had no such first hand knowledge but allowed that the explanations were both plausible and probable.

This little exercise was not an audit. All of our results are non-quantitative. In fact, we did little more than scratch the surface. But the results convinced us of the importance to R&M planning of continuing in this same direction. We know of no more efficient way to capture similar information, and we believe that this kind of information is an essential complement to using the MDC data to identify candidate systems for R&M improvement.

Finally, we went into this exercise expecting to find that most of the interbase variability was due to just plain reporting errors. We did not find this at all. Rather, we found that the MDC data were reporting what was going on fairly accurately. And although the MDC data were telling us a lot about what, they were not telling us enough about why. We conclude that the MDC data are quite useful for raising questions and for focusing more indepth queries. Both steps must be performed to do a useful job of screening. Furthermore, indepth looks are required to decide about the desirability and even feasibility of improving either the reliability or maintainability of candidate systems or subsystems.

V. CONCLUSION

This Note describes only a first and possibly incomplete effort to meet our objectives of (1) devising a method for screening candidates for R&M improvement, (2) understanding how to conduct such an analysis and to direct future research in this area, and (3) suggesting ways of tracking the results of R&M improvement programs. We do not claim our results represent the final destination of such research, but rather a start in the right direction. However, we have offered a useful, workable method for undertaking and continuing this analysis and made extensive inroads toward identifying R&M improvement candidates. Moreover, our research and analyses have led us to some unexpected insights that helped shape our conclusions and might help guide future research.

Our two-step method of identifying candidates for R&M improvement programs from the MDCS database might appear time-consuming or tedious, but time and effort must be invested to work with such a large database. The screening method we devised yields useful results. The MDCS database, though almost unwieldy as it stands, is a valuable source for initial identification of aircraft reliability and maintainability problems. Our two-step method tames this large, complex, and rich database by distilling and simplifying it, preparing useful metrics for reading the resulting analysis data files, and presenting the information in a helpful way. To summarize once again: In step one we reduced and simplified the MDCS/D056 data by making the successively smaller and more manageable Bases File, Jobs File, and Counts File, which helped define maintenance jobs and count them. In step two we used these files to obtain insights about the R&M status of the F-16AB Worldwide Fleet, identifying the candidates for improvement programs. In what might be considered a third step, we tried to confirm this information with site investigations at two bases.

Our working assumption was that a lot of maintenance activity on a particular system or component (as indicated by the data in our analysis files) would suggest that it has either a reliability problem, a maintainability problem, or both. Our site investigations to examine the reasons for variability among bases revealed this assumption is not always fair. The MDCS data do accurately report that there is maintenance activity--when, where, what kind--but they do not confirm that such activity is necessarily an R&M problem. In short, they are not enough by themselves to make final decisions for selecting candidate systems, subsystems, or components for R&M improvement programs. Nevertheless, they are very useful for raising questions and for focusing more indepth queries, especially before site visits. We believe it is essential to follow the initial screening process with such site investigations, to check the reasons for high maintenance activity and to better understand data variation at different bases, before instituting an R&M improvement program on a particular system.

As our investigations showed, the variability among bases is important, and the reasons for it can be enlightening. For instance, we learned that maintenance requirements on a particular system can change over time, even at the same base, and that lots of reported maintenance actions are the results of one-time problems, rather than of recurring problems. And interbase variation is not due simply to reporting error. For a more accurate picture of R&M activity, the information gained from site visits should be a necessary complement to that acquired with our proposed method of identifying candidates for R&M improvements. Perhaps future studies will work with data covering several years--rather than the two we used--in order to produce an even more accurate picture of R&M problems.

Appendix A

SELECTED F-16 A/B WORK UNIT CODES

01000–09999	Support general
12CA0	Canopy assembly
14000	Flight control system
14B00	Primary flight control actuators
14BB0	Integrated servo actuator, horizontal tail
13BAA	Main landing gear, left hand axle assembly
13DA0	Main landing gear, wheel and tire assembly
13DAA	Main landing gear wheel assembly
13DAB	Main landing gear tire
13DBA	Nose landing gear wheel assembly
13DBB	Nose landing gear tire
41A00	Environmental system
41ACA	Cabin air temperature control
44AAB	Landing light
44AAE	Navigation/formation wingtip light
74A00	Fire control radar set
74AB0	Low power RF unit

SOURCE: Aircraft Maintenance Work Unit Code Manual, USAF/EPAF Series F-16 A/B Aircraft, T.O. 1F-16A-06, General Dynamics, Fort Worth Division, 25 February 1985.

Appendix B

PARTIAL LIST OF WHEN DISCOVERED CODES

A	Before flight--abort
B	Before flight--no abort
C	In-flight abort
D	In-flight--no abort
E	After flight
F	Between flights by ground crew (not scheduled inspection)
G	Ground alert--not degraded
H	Through-flight inspection
J	Preflight inspection
K	Hourly postflight inspection
M	Phased inspection
N	Ground alert--degraded
P	Functional check flight
Q	Special inspection
R	Quality control check
S	Depot level maintenance
T	During scheduled calibration
U	Oil analysis
V	During unscheduled calibration
W	In-shop repair and/or disassembly for maintenance
X	Engine test stand operation
Y	Upon receipt or withdrawal from supply stocks
Z	AGM under wing check
2	Malfunction analysis and recording equipment or subsequent data analysis
4	Corrosion control inspection

SOURCE: Aircraft Maintenance Work Unit Code Manual, USAF/EPAF Series F-16 A/B Aircraft, T.O. 1F-16A-06, General Dynamics, Fort Worth Division, 25 February 1985.

Appendix C

PARTIAL LIST OF HOW MALFUNCTIONED CODES

This appendix contains a partial list of codes used to describe malfunctions. For convenience it is separated into four groups:

Table C.1: Avionics/Electrical/Computer

Table C.2: Physical Mechanical

Table C.3: No Defect Found

Table C.4: Engine Related

Table C.1

AVIONICS/ELECTRICAL/COMPUTER GROUP

1	Faulty tube, transistor, or integrated circuit
25	Capacitance incorrect
28	Conductance incorrect
29	Current incorrect
37	Fluctuates, unstable, or erratic
51	Fails to tune or drifts
64	Incorrect modulation
65	High voltage standing wave ratio
80	Burned out or defective lamp, meter, etc.
88	Incorrect gain
103	Attack display malfunction
169	Incorrect voltage
242	Failed to operate or function--reason unknown
254	No output
255	Incorrect output
290	Fails diagnostic/automatic test
350	Insulation breakdown
383	Lock on malfunction
450	Open
457	Oscillating
472	Fuse blown or defective circuit protector
567	Resistance incorrect
580	Temperature sensitive
583	Scope presentation incorrect or faulty
607	No-go indication--specific reason unknown
609	Out of track/fails to track
615	Shorted
625	Gating incorrect
626	Inductance incorrect
627	Attenuation incorrect
631	Bias voltage incorrect
635	Sensitivity incorrect
637	Triggering incorrect
644	BIT indicated fault
649	Sweep malfunction
652	Automatic align time excessive
653	Ground speed error excessive
654	Terminal error--CEP excessive
655	Terminal error--range excessive
656	Terminal error--azimuth excessive
657	Distance measurement error--navigation equipment
658	Bearing destination (station) error
672	BIT false alarm
692	Video faulty
693	Audio faulty
695	Sync absent or incorrect

Table C.1--continued

698	Faulty card--program or checkout
718	Improper response to mechanical input
721	Improper response to electrical input
816	Impedance incorrect
824	Gyro processes
901	Intermittent
939	Unable to load program
941	Non-programming halt
942	Illegal operation or address
943	Data error
949	Computer error/defect
956	Computer equipment malfunction
957	No display
959	Fails to transfer to redundant equipment
962	Low power--electronic
964	Poor spectrum
969	Cannot resonate input cavity
974	Does not track tuning curve
982	Frozen tuning mechanism
987	Input pulse distortion
988	Loss of vacuum
989	Low coolant flow rate
991	Out of band frequency

Table C.2

PHYSICAL MECHANICAL GROUP

2	Servicing
6	Contacts/connection deffective
8	Noisy
20	Worn, chafed, or frayed
70	Broken
86	Improper handling
105	Loose or damaged bolts, nuts, screws, etc.
111	Burst or ruptured
116	Cut
127	Adjustment or alignment improper
135	Binding, stuck, or jammed
167	Torque incorrect
170	Corroded--mild to moderate
190	Cracked
230	Dirty, contaminated, or saturated by foreign material
300	Grounded electrically
301	Foreign object damage
303	Bird strike damage
334	Temperature incorrect
372	Metal or magnetic plug
381	Leaking--internal or external
410	Lack of or improper lubrication
425	Nicked
525	Pressure incorrect
553	Does not meet specification, drawing, etc.
561	Unable to adjust to limits
585	Sheared
599	Travel or extension incorrect
602	Failed or damaged due to malfunction of associated equipment
622	Wet/condensation
632	Expended--thermal battery, fire extinguisher, etc.
651	Air in system
667	Corroded--severe
669	Potting material melting (revision process)
690	Vibration excessive
710	Bearing failure or faulty
730	Loose
731	Battle damage
750	Missing
780	Bent, buckled, collapsed, dented, distorted, etc
782	Tire tread area defective - use cut, delaminated
783	Tire sidewall damaged or defective
784	Tire bead area damaged or defective
785	Tire inside surface damaged or defective
846	Delaminated

Table C.2--continued

865	Protective coating/sealant missing or defective
884	Lead broken
900	Burned or overheated
916	Impending or incipient failure
917	Impending failure or latent defect
932	Does not engage, lock, or unlock correctly
948	No defect - operator error
972	Damaged input probe

Table C.3

NO-DEFECT-FOUND GROUP

799	No defect
800	No defect--removed to facilitate other maint.
804	No defect--removed for scheduled maint. or mod
812	No defect--indicated defect caused by other equip.

Table C.4

ENGINE RELATED GROUP

Observed or Recorded Conditions

69	Flame-out
177	Fuel flow incorrect
191	High EGT
192	Overtemperature
193	Excessive stalls
195	Exceeding qual check temp limit
196	Excessive oil from breather
197	Fuel leakage
198	Contaminated fuel
199	High or low oil consumption
200	Oil leakage
201	Contaminated oil
202	Low oil presure
203	High oil pressure
204	Smoke or fumes in cockpit
205	Start or off idle stagnation
206	Steady state stagnation
207	Augmentor induced stagnation
208	Augmentor nozzle mechanism deterioration
209	Internal noise or shutdown/start
210	Servicing with improper grade of fuel or oil
211	Corroded internal surfaces
212	Corroded external surfaces
221	APU will not carry load
222	Engine shuts down after start (APU)
223	Control system component malfunction
224	Backup/emergency control system failure
225	Bleed air malfunction
226	Engin start time beyond limits
227	Compressor variable geometry improper
253	Misfires
314	Slow acceleration
315	RPM fluctuation incorrect
317	Hot start
464	Overspeed
475	Engine failed to start
513	Compressor stall
537	Low power or thrust

Identified Components

136	Damaged/cracked stator case
137	Damaged/cracked fan stator vanes
138	Fan blade damaage
139	Cracked or warped inlet guide
140	Frozen fan

Table C.4--continued

142	Compressor damage due to failure or seizures
143	Damaged/cracked compressor case
144	Compressor rotor change (other than FOD)
145	Cracked diffuser cases
146	Combustion damage
147	Combustion case burn or hot spot
148	Damaged/cracked turbine frame/case
149	Flame holder or fuel rings/bars damaged
150	Thrown, damaged, or failed buckets
151	Turbine wheel failure
152	Turbine nozzle failure
153	Turbine damage due to material failure
154	Engine or afterburner fire damage
155	Engine or aircraft mount failure
156	Afterburner or augmentor problem repair
158	Accessory drive gear
160	Bearing and/or support failure
161	Bearing failure
162	Scavenger pump failure
174	QEC discrepancy
277	Fuel nozzle coking
279	Spray pattern defective
458	Out of balance
Condition Monitoring	
175	Adverse EGT/TIT trend
176	Adverse RPM trend
178	Vibration trend
179	Exhaust pressure ratio trend
180	Adverse oil consumption trend
181	Adverse fuel flow trend
182	Perf. trend (compressor section)
183	Perf. trend (combustion section)
184	Perf. trend (turbine section)
186	Removed for further test cell diagnostic check
187	Borescope trend (compressor section)
188	Borescope trend (combustor section)
189	Borescope trend (turbine section)
Chance Occurrences	
476	Damaged by solid foreign objects
477	Damaged by ice
478	Damaged by rags, rubber, etc.
480	Damaged by aircraft accident
482	Excessive G force inspection
483	Dummy engine transaction
Managerial Decision	
866	Expiration of max time (engines, modules, etc.)
867	Transfer time limit

Table C.4--continued

868	Removed/rolled back for failed ext. component
870	Removed for research, test, or diagnostic
874	Storage damage
875	Removed for cannibalization
876	Non-tech order directed removal
877	Tech order identified components
878	Removed to perform sched/special inspection
879	Expiration of max cycles/sorties (engines & comps)
880	Opportunistic maintenance removal
881	Removal to perform minor inspection

Appendix D

PARTIAL LIST OF ACTION TAKEN CODES

A	Bench checked and repaired
B	Bench checked--serviceable
C	Bench checked--repair deferred
D	Bench checked--transferred to another base
E	Initial installation
F	Repair
G	Repair and/or replacement of minor parts, hardware, etc.
H	Equipment checked--no repair required
J	Calibrated--no adjustment required
K	Calibrated--adjustment required
L	Adjust
M	Disassemble
N	Assemble
P	Removed
Q	Installed
R	Remove and replace
S	Remove and reinstall (to facilitate other maintenance)
T	Remove for cannibalization
U	Replace after cannibalization
V	Clean
X	Test, inspect, service (Ops check)
Y	Trouble shoot
Z	Corrosion repair

SOURCE: Aircraft Maintenance Work Unit Code Manual, USAF/EPAF Series F-16 A/B Aircraft, T.O. 1F-16A-06, General Dynamics, Fort Worth Division, 25 February 1985.

Appendix E

HOW MALFUNCTIONED AND ACTION TAKEN CODES FOR OTHER JOBS

Avionics/Electrical/Computer Group

942 Illegal operation or address
698 Faulty card--program or checkout

Engine Related Group

Observed or Recorded Conditions

198 Contaminated fuel
201 Contaminated oil
210 Servicing with improper grade of fuel or oil

Chance Occurrances

476 Damaged by solid foreign objects
477 Damaged by ice
478 Damaged by rags, rubber, etc.
480 Damaged by aircraft accident
482 Excessive G force inspection
483 Dummy engine transaction

Management Decision

866 Expiration of max time (engines, modules, etc.)
867 Transfer time limit
870 Removed for research, test, or diagnostic
874 Storage damage
875 Removed for cannibalization
877 Tech order identified components
878 Removed to perform sched/special inspection
879 Expiration of max cycles/sorties (engines & comps)
880 Opportunistic maintenance removal

Physical Mechanical Group

2 Servicing
86 Improper handling
116 Cut
167 Torque incorrect
230 Dirty, contaminated, or saturated by foreign material
300 Grounded electrically
303 Bird strike damage
553 Does not meet specification, drawing, etc.
602 Failed or damaged due to malfunction of associated equipment
622 Wet/condensation
632 Expended--thermal battery, fire extinguisher, etc.
731 Battle damage
948 No defect--operator error

No Defect Group

800 No defect--removed to facilitate other maint.
804 No defect--removed for scheduled maint. or mod.

Also if ATC = T

Appendix F

HOW MALFUNCTIONED AND ACTION TAKEN CODES FOR NO-DEFECT-FOUND JOBS

Avionics/Electrical/Computer Group

672 BIT false alarm

No Defect Group

799 No defect

Also if ATC = X OR ATC = Y OR ATC = H OR ATC = J

Appendix G

CHARACTERISTICS OF REMOVE & REPLACE JOBS, HILL AFB, F-16 A/B, 1986

Description	Code	No. of Jobs	Pct. of Jobs	Cum. Pct. Jobs
When Discovered Code				
In-flight, no abort	D	3358	55.3	55.3
Between flights, ground crew	F	1555	25.6	80.9
Phased inspection	M	567	9.3	78.0
Before flight, abort	A	297	4.9	95.2
Other	--	294	4.8	100.0
Total		6071	100.0	
How Malfunctioned Code				
Failed to operate, reason unknown	242	1213	20.0	20.0
Incorrect output	255	557	9.2	29.2
Worn, chaffed, frayed	20	428	7.0	36.2
Broken	70	391	6.4	42.6
Burned out/defective	80	349	5.7	48.4
Failed diagnostic/auto test	290	343	5.7	54.0
BIT indicated fault	644	332	5.5	59.5
Leaking	381	310	5.1	64.6
Cracked	190	265	4.4	69.0
Loose bolts, etc.	105	187	3.1	72.1
Binding, stuck, etc.	135	134	2.2	74.3
Audio faulty	693	109	1.8	76.1
Burned or overheated	900	84	1.4	77.5
Fluctuates, erratic	37	82	1.4	78.8
Intermittent	901	78	1.3	80.1
Shorted	615	71	1.2	81.3
Pressure incorrect	525	70	1.2	82.4
Video faulty	692	69	1.1	83.5
No output	254	67	1.1	84.6
Loose	730	65	1.1	85.7
Improper response to electrical input	721	63	1.0	86.8
Incorrect voltage	169	61	1.0	87.8
Other	--	743	12.2	100.0
Total		6071	100.0	
Action Taken Code				
Remove & replace	R	5201	85.7	85.7
Remove	P	870	14.3	100.0
Total		6071	100.0	

Appendix H

CHARACTERISTICS OF NO-DEFECT-FOUND JOBS, HILL AFB, F-16 A/B, 1986

Description	Code	No. of Jobs	Pct. of Jobs	Cum. Pct. Jobs
When Discovered Code				
In-flight, no abort	D	3190	48.2	48.2
Between flights, ground crew	F	2347	35.4	83.6
Phased inspection (fix phase)	M	675	10.2	93.8
Other	--	409	6.2	100.0
Total		6621	100.0	
How Malfunctioned Code				
No defect	799	5451	82.3	82.3
Failed to operate, reason unknown	242	372	5.6	87.9
Other	--	798	12.1	100.0
Total		6621	100.0	
Action Taken Code				
Test, inspect, service	X	3027	45.7	45.7
Equipment checked--no repair	H	1872	28.3	74.0
Trouble shoot	Y	940	14.2	88.2
Remove & replace	R	352	5.3	93.5
Other		782	11.8	100.0
Total		6621	100.0	

Appendix I

CHARACTERISTICS OF MINOR REPAIR JOBS, HILL AFB, F-16 A/B, 1986

Description	Code	No. of Jobs	Pct. of Jobs	Cum. Pct. Jobs
When Discovered Code				
Phased inspection	M	7985	78.0	78.0
In-flight, no abort	D	1437	14.0	92.1
Other	--	811	7.9	7.9
Total		10233	100.0	
How Malfunctioned Code				
Loose, damaged, bolts, etc.	105	6096	59.8	59.8
Corroded	170	1312	12.8	72.4
Adjustment improper	127	506	4.9	77.3
Loose	730	371	3.6	81.0
Leaking	381	342	3.3	84.3
Worn, chafed, or frayed	20	308	3.0	87.3
Broken	70	144	1.4	88.7
Incorrect output	255	136	1.3	90.1
Other	--	1018	9.9	9.9
Total		10233	100.0	
Action Taken Code				
Repair/replace minor parts	G	7217	70.5	70.5
Adjust	L	1511	14.8	85.3
Corrosion repair	Z	953	9.3	94.6
Other		552	5.4	100.0
Total		10233	100.0	

Appendix J

CHARACTERISTICS OF OTHER JOBS, HILL AFB, F-16 A/B, 1985

Description	Code	No. of Jobs	Pct. of Jobs	Cum. Pct. Jobs
When Discovered Code				
Between flights, ground crew	F	2534	55.0	55.0
Phased inspection (fix phase)	M	1162	25.2	80.3
In-flight no abort	D	514	11.2	91.4
Other	--	909	8.6	100.0
Total		4605	100.0	
How Malfunctioned Code				
No defect (FOM)	800	1185	25.7	25.7
Dirty, contaminated, etc.	230	991	21.5	47.3
Removal for cannibalization	875	491	10.7	57.9
No defect	799	489	10.6	68.5
Removed for schededuled maintenance or modification	804	432	9.4	77.9
Expended	632	363	7.9	85.8
Time up	866	151	3.3	89.1
Defect in associated equipment	812	148	3.2	92.3
Other	--	355	7.7	100.0
Total		4605	100.0	
Action Taken Code				
Remove for cannabilization	T	965	21.0	21.0
Remove	P	943	20.5	41.4
Remove & replace	R	765	16.6	58.0
Clean	V	748	16.2	74.3
Repair/replace minor parts	G	456	9.9	84.2
Remove & reinstall (FOM)	S	330	7.2	91.4
Other		398	8.6	100.0
Total		4605	100.0	

END

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